Frederic Nicholls

NATIONAL

# Electric Light

ASSOCIATION.

TWENTIETH CONVENTION

NIAGARA FALLS, N. Y.
June [illegible] 9th and 10th, [illegible]7

PUBLISHED BY ORDER OF THE EXECUTIVE COMMITTEE.

NEW YORK
THE JAMES KEMPSTER PRINTING COMPANY
[illegible] LIBERTY STREET
[illegible]

# ★ NATIONAL

# Electric Light

# ASSOCIATION.

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## CONVENTIONS OF THE ASSOCIATION

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| *First* | Chicago, February 25, 26, 1885 |
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| *Eleventh* | Kansas City, February 11, 12, 13, 14, 1890 |
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| *Nineteenth* | New York, May 5, 6, 7, 1896 |
| *Twentieth* | Niagara Falls, June 8, 9, 10, 1897 |

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†E. H. Stevens

*Elected in place of J. J. Burleigh, promoted.

†Elected in place of A. M. Young, promoted.

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JAMES I. AYER, Chairman

W. C. BRYANT GEO. W. DAVENPORT

## ORDER OF BUSINESS

TUESDAY, June 8th, 1897.

FIRST SESSION, 10.45 A. M.

1. Announcements
2. President's Address
3. REPORT. Committee on Data
4. REPORT. Committee on Finance
5. Announcements

SECOND SESSION, 2.30 P. M.

1. Announcements
2. Paper—"The Establishment of a Base Price for Current." By J. B. CAHOON
3. Topic—"Theft of Current, and How To Deal With It"
4. REPORT. Committee on Standard Electrical Rules
5. Paper—"Municipal Lighting." By W. WORTH BEAN
6. Executive Session

# MINUTES

## OPENING OF THE CONVENTION

The association met in the International Hotel Parlors, Tuesday, June 8th, 1897, and the meeting was called to order at 10.45 a. m. by the president, Frederic Nicholls, who said:

"The members are rather slow in assembling. I call the meeting to order without any unnecessary delay. We intend to try to conduct the proceedings of the convention in a business-like manner, and I think that if the members do not attend promptly we had better go on with the work of the convention. I see our first vice-president, Mr. Clay, is present, and I would ask him to support me on the platform. Judge Armstrong, one of our valued ex-presidents, is here, I am glad to say; I also saw Mr. Ayer somewhere about, but I do not know whether he is in the hall or not. I should like to see these gentlemen on the platform."

## ANNOUNCEMENTS

THE PRESIDENT: We have been favored with a number of letters of invitation to visit the various industries that are being operated by Niagara power, and I will read them in their rotation.

The president read the following letters:

"NIAGARA FALLS, N. Y., April 27th, 1897.

"FREDERIC NICHOLLS,

"President The National Electric Light Association,

"Toronto, Ontario.

"DEAR SIR: As our city has been favored by being selected by your association as the place at which it is to hold its annual convention this year, and as the power development here may be of interest to at least some of the members of your association, it affords the Niagara Falls Power Company great pleasure to extend to you and, through you, to the members of your association a cordial invitation to visit its plant and power-house at the time of your convention here, June 8th, 9th and 10th. Should the members of your association desire to visit the power-house in a body, we shall esteem it a great favor if you will kindly advise us in advance of the day and hour which will best suit your convenience.

"Very truly yours,

"L. A. GROAT,

"Secretary."

"Niagara Falls, N. Y., April 20th, 1897.

"Frederic Nicholls, Esq.,
"President National Electric Light Association,
"New York City.

"Dear Sir: We shall be pleased to have you and the members of your association visit our power-house, or other institutions located on our property, during your convention to be held in our city June 8th, 9th and 10th next.

"Yours truly,
"Niagara Falls Hydraulic Power and Manufacturing Company,
"By A. Schoellkopf,
"Secretary and Treasurer."

"Buffalo, N. Y., May 11th, 1897.

"George F. Porter,
"Secretary National Electric Light Association,
"New York.

"Dear Sir: I note with much pleasure that your association is to hold its next convention at Niagara Falls June 8th, 9th and 10th. We are pleased to extend to you the courtesies of our company, and shall be pleased to have your members visit our station at any and all times. I am,

"Respectfully yours,
"Geo. Urban, Jr.,
"President."

"NIAGARA FALLS, N. Y., May 15th, 1897.

"MR. GEO. F. PORTER,
"Secretary National Electric Light Association,
"New York.

"DEAR SIR: We are pleased to extend herewith invitation to the delegates who will attend the twentieth convention of the National Electric Light Association, to be held in this city June 8th, 9th and 10th, to visit our works at that time.

"We shall deem it a favor if you can advise us two or three days in advance on what date you will make it convenient to see us, and we shall use our best endeavors to have matters so arranged as to conveniently take care of the visitors.

"Yours very truly,
"THE CARBORUNDUM COMPANY,
"W. H. A."

"NEW YORK, May 28th, 1897.

"GEORGE F. PORTER, ESQ.,
"Secretary and Treasurer National Electric Light Association,
"136 Liberty street, New York, N. Y.

"DEAR SIR: On behalf of this company, I take pleasure in tendering to the members of your association attending your annual convention at Niagara Falls, N. Y., on June 8th, 9th and 10th, 1897, free service over our long-distance telephone lines before 9 a. m. and after 6 p. m.

"Yours truly,
"EDW. J. HALL,
"Vice-President and General Manager."

"NEW YORK, June 4th, 1897.

"MR. FREDERIC NICHOLLS,
"National Electric Light Association,
"136 Liberty Street, New York City.

"DEAR SIR: I am instructed by Mr. Montgomery Maze, manager of the Grand Central Palace, to extend to your association an invitation to meet in this building next year, in case you decide to hold your next meeting in this city, and if it shall seem best for you to meet elsewhere, the invitation will stand until such time as you decide to meet in New York.

"All the accommodations of the building, which most of your members are familiar with, will be at your disposal without cost to your association, and whatever assistance we can give you to make your meeting a successful one, will be cheerfully extended.

"B. E. GREENE,
"Rental Agent."

The following letters of regret were also read:

"CORNELL UNIVERSITY,
ITHACA, N. Y., May 17th, 1897.

"GEORGE F. PORTER, ESQ.,
"136 Liberty Street, New York, N. Y.

"DEAR SIR: Your letter containing an invitation to attend the twentieth convention of the association is at hand. It would give me great pleasure to be present at the meeting, and unless absolutely prevented by other engagements I shall endeavor to be at hand.

"Yours very truly,
"EDW. L. NICHOLS."

"MONTREAL, May 20th, 1897.

"G. F. PORTER, ESQ.,

"Secretary National Electric Light Association.

"MY DEAR SIR: I beg to thank you for your very kind invitation to the convention of the Electric Light Association, but regret that engagements here, and infirmity remaining after illness, must prevent me from being present.

"Truly yours,

"WM. DAWSON."

"MONTREAL, May 17th, 1897.

"G. F. PORTER, ESQ.

"MY DEAR SIR: I beg to acknowledge with many thanks your communication of the 14th instant, informing me that the twentieth convention of the National Electric Light Association is to be held at Niagara Falls on the 8th, 9th and 10th of June. It would give me very great pleasure to be present, especially on the occasion of the president's chair being occupied by a Canadian who is so much esteemed as Mr. F. Nicholls. I fear, however, that important business will prevent my leaving Montreal at the time set apart for the convention.

"Trusting that the meeting will be a great success, believe me to remain,

"Yours truly,

"HENRY T. BOVEY."

"THE UNIVERSITY, GLASGOW, July 7th, 1897.

"For the address which I have had the honor to receive from the National Electric Light Association

of America, on the occasion of the Jubilee of my Professorship of Natural Philosophy in the University of Glasgow, I desire to express my warmest thanks. I value very highly the great honor which it has conferred upon me. The friendly appreciation of my scientific work contained in the address is most gratifying.

"I feel deeply touched by the great kindness to myself, and the good wishes for my welfare, of which it gives expression.

"KELVIN."

THE PRESIDENT: I have also a letter from the Chamber of Commerce, Nashville, Tenn., which I defer reading until the afternoon session. I understand that a number of gentlemen are here, some from Indianapolis, some from Omaha—this is a letter from Nashville—and other places,—all for the purpose of inviting your association to visit their respective cities. I think that this letter is the only one before me at this moment, and I will defer it until the others are read at the afternoon meeting of the convention.

The president then read a letter from Wm. S. Aldrich, West Virginia University.

"WEST VIRGINIA UNIVERSITY,
"MORGANTOWN, WEST VA., June 4th, 1897.

"MR. FREDERIC NICHOLLS,
"President National Electric Light Association,
"Toronto, Canada.

"DEAR SIR: After the late Hartford meeting of the American Society of Mechanical Engineers, I

called on some prominent New York parties interested in the matter of my paper before that meeting, and they suggested that it might be well to bring the principal features of the above paper to the attention of your National Electric Light Association in discussion of the report of the Committee on Data. I have received copy of the latter, and herewith inclose you copy of my paper alluded to above.

"I shall endeavor to be present at the coming Buffalo meeting of the National Electric Light Association by Thursday morning, June 10th, 1897. I can scarcely be present earlier, on account of our annual commencement, which occurs here on the 9th instant.

"If it should be your pleasure, I shall prepare a brief outline of my American Society of Mechanical Engineers paper, to introduce discussion of report of the Committee on Data at that time, advocating the extension of the power plant ratings still further along the most advanced and most recognized lines of engineering development, that it be based on the British thermal unit standard, as now in vogue, of course, for pumping plants. Believe me,

"Very truly yours,

"WM. S. ALDRICH."

# ADDRESS OF PRESIDENT NICHOLLS

*Members of the National Electric Light Association.*

GENTLEMEN: In arriving at a decision as to the most suitable place at which to hold the twentieth convention of the National Electric Light association, the executive committee and your president were guided largely by the desire to select a spot where our members could have some practical illustration of the most recent advances in electrical development as applied to everyday commercial use on an extended scale.

Niagara Falls, New York, appeared to offer superlative inducements as our place of meeting, judged by this standard, and was accordingly given the preference; and with a knowledge of the programme that has been prepared for the instruction of our members, and the many interesting features for the entertainment of themselves and their friends, I am confident that before the close of the convention those present will be unanimously of the opinion that our choice was wisely made.

When we consider that only five years since many of us were in attendance at the fifteenth convention of the Association, held in Buffalo, and were listening to the discussion that followed Dr. Carl Hering's paper on "Transmission of Power," even the most sanguine of us but little imagined that in half a decade we should be holding our twentieth convention at Niagara Falls principally with the object of seeing and realizing the actual application of

motive power derived from the falls to some of the most novel and most important industries of the country.

To "harness Niagara" had long been a dream, but is now an actuality, and who can foretell the resultant progress and advancement that we may be destined to celebrate within the next few years.

There is no parallel in history for such rapid development of any industry as that of the manufacture of electrical apparatus and its application; or, to be strictly correct, and to quote ex-president of the association Mr. M. J. Francisco, who is an authority on the subject, the only parallel was when the world was created in six days out of nothing. Five years ago, we were discussing the possibilities of transmitting power in small units to moderate distances; to-day, the problem is solved, and innumerable installations *are* transmitting power in large quantities for long distances, and yet we have only crossed the threshold.

In this connection, I am of the opinion that the lecture to be given to-morrow evening by Mr. L. B. Stillwell will serve as a tidal mark. At the Buffalo convention we occupied ourselves in discussing the possibility, or otherwise, of transmitting Niagara power to Buffalo; Mr. Stillwell's paper will set forth the various actual applications of Niagara power at the present time, including transmission to Buffalo, and future presidents of this association will, in all probability, refer to his paper and draw comparisons when adverting to the strides which will by that time have been made in the wider utilization of this mighty power which, for countless ages, has been simply running to waste so far as any economic use is concerned, and apart from its value as the greatest scenic wonder of the world.

I fully appreciate the honor of presiding at this meeting which, for the reasons I have just referred to, will be embodied in the annals of the association as marking an historic epoch in the advancement of the science of electricity as applied to industry, and it is, therefore, with more than ordinary satisfaction that I am authorized to state that at no previous period has this association been so prosperous, shown greater vitality, or commanded such respect. It is now an acknowledged authority on matters electrical, its membership confers a privilege that has more than a sentimental value, and its gathering strength will offer a bar to the use of powers, municipal or corporate, unjustly or arbitrarily directed to the purpose of destroying the capital investment of those who look to it for protection.

In union is strength, and our membership to-day numbers more active members than ever before; and the financial statement to be presented in due course by the chairman of the finance committee will show that, after making provision for all expenditures necessary to maintain the usefulness of the association, an unusually large credit balance is at your disposal.

It is certainly cause for congratulation that increasing prosperity has been followed by an access of dignity and influence, and that the more recent meetings have been remarkable for the greater interest taken in the actual work of the association, and the lesser attention given to the merely social and entertainment features of the programme.

The desire to make the twentieth convention notably a business meeting has so far predominated that we have neither asked nor accepted any favors other than from the electric power companies and several of the manufacturing establishments using electric power for the operation of their works.

Although several delightful and interesting excursions have been arranged for, the association has made, on behalf of its members, a business-like arrangement for the several trips and excursions set forth in the programme of the convention, preferring to pay our own way rather than tax the courtesy of the transportation and other companies by accepting deadhead privileges.

In view of the fact that I have had occasion to communicate with our members from time to time during the past year by the issuance of printed "Interim Reports," referring to the work undertaken by your executive, it is unnecessary to give an account of my stewardship in this address; but I may say that many matters of urgent importance are pressing for settlement, which will, doubtless, receive the most careful attention at your hands during the next few days.

The list of papers to be read at this convention is an exceptionally good one, and the authors are of more than continental reputation, and I therefore trust that our members will show their appreciation of the care and study given to the preparation of these papers, by being present in force at every session and taking an active part in the discussions that will ensue. Notwithstanding the progress that has been made in the perfection of apparatus and the application of new principles, there never was a time when there was more to learn than now, and no more fitting occasion is likely to present itself to us to familiarize ourselves with the latest procedure in our chosen profession; and the papers to be read, and the discussions thereon, will find hundreds of thousands of readers and students, thanks to the electrical journals, of which we are all so justly proud.

No other art, science, industry or profession has been so well and faithfully served by an enlightened and progressive technical press as our own, and who can estimate the fair share of credit justly their due for the part they have taken in aiding and advancing the introduction of electro-motive force in its many and various applications.

As we have a lengthy programme before us, and several important reports of committees to receive and discuss before we adjourn for midday recess, I now declare the twentieth convention of the National Electric Light Association opened and ready for the transaction of business.

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THE PRESIDENT: This morning's session, as is usual with the opening session of the convention, will necessarily be short, and we will take up the usual reports of committees in their regular order. Some of the chairmen, I understand, will ask to have their reports deferred to a subsequent session, but I would ask the gentlemen who are present, and those who are not, to make an effort to attend the first actual business meeting of the convention, this afternoon. I think it is called for two o'clock. That will be a little early; I will say half-past two o'clock, in order to give everybody an opportunity to be present after luncheon.

The first order on the programme is the report of the Committee on Standard Candle Power of Incandescent Lamps, by Dr. Louis Bell, chairman. I might say, in this connection, that a very great deal of work has been done toward this end since the last meeting of the association, in New York. Very few of you know the amount of work and the amount of correspondence that has taken place between the chairman,

Dr. Bell, and Mr. James I. Ayer, our past president, who has taken a great interest in the subject, and I think that this question is more nearly approaching a solution than ever before. I have never, in my whole experience, felt the utter hopelessness of fighting against time as I have this year, in trying to get so many matters absolutely concluded during my administration. Some of them have been happily carried to a successful conclusion. Others are so far advanced that I think my successor will have no difficulty in bringing them to such a point that before the next convention meets many of these important questions of standardization will have been applied to a good many of the leading articles of the electrical business. I will call upon Mr. Ayer as one of the committee.

Mr. Ayer: Mr. President, Dr. Bell, at the last moment, telegraphed me that he would be unable to come to Niagara, and has furnished me with a rough draft of a report. In fact, we sat up nearly all night engaged in getting the report into shape. I have only a pencil draft of it, not suitable to be read, and I would ask that the matter be laid over until to-morrow, or, perhaps, the next day, to give us an opportunity to have the report prepared for presentation. It is of interest, and, I think, will prove to be of value.

The President: Gentlemen, is it your pleasure that the committee be allowed to report at a subsequent session? All those in favor say aye. Contrary, no.

Carried.

The President: The next report is that of the Committee on Data, Mr. H. M. Swetland, chairman.

Mr. Swetland read a synopsis of the following report:

## REPORT OF THE COMMITTEE ON DATA

*Mr. President:*

For a number of years this committee made reports of the cost of electricity in pounds of coal as shown in actual practice, the information having been obtained by correspondence.

Following the instructions of the last convention, the committee have confined the work for the past year to the personal investigations of an expert, and on this basis this report is respectfully submitted.

It is to be regretted that a large majority of station managers do not desire to have their work made generally public, and, as usual, the efforts of the committee have been handicapped by this feeling. That a free interchange of experience would be vastly beneficial is clearly proven by the superior results obtained from the organized effort in this direction among the Edison companies.

We have called our expert, therefore, to consider in detail the various losses which come under his observation, and have endeavored to cover as wide a range of equipment as was possible under the circumstances.

With this brief explanation the subjoined report is respectfully submitted.

H. M. Swetland,
*Chairman.*

*To the Committee on Data of the National Electric Light Association.*

Gentlemen: In your last report you submitted returns from eighty-one electric light stations using coal as fuel, showing the following results obtained in actual practice:

| | Watt hours per lb. coal. | Lbs. coal per kilowatt hour. |
|---|---|---|
| Maximum.......... | 237 | 4.22 |
| Minimum.......... | 33 | 30.3 |
| Average........... | 108 | 9.26 |

In your conclusions you called attention to the fact that, at the Chestnut Hill pumping station at Boston, an effective horse-power had been developed on 1.34 pounds of coal per hour. If a steam dynamo can be constructed and operated as efficiently as was this steam pump, it will deliver $746 \div 1.34 = 557$ watt hours per pound of coal and require only $1{,}000 \div 557 = 1.8$ pounds of coal per kilowatt hour.

I am asked to account for this difference between the actual efficiency attained in the every-day practice of electrical stations and the efficiency apparently attainable in other applications of power.

In the first place, the standard which you have set is, purposely, no doubt, extremely high. The Chestnut Hill engine holds the world's record for steam efficiency, having developed an indicated horse-power on a consumption of 11.22 pounds of steam per hour, and embodies all the refinements of modern engineering. There is no reason why an equally efficient engine can not be built and attached to a dynamo,

should it appear advisable to incur the expense of all this refinement for the attainable difference in expense of maintenance.

There are steam dynamos now running on thirteen pounds of steam per indicated horse-power, which, with a difference of fifteen per cent between the indicated and electrical horse-power, and an evaporation of ten pounds of water per pound of coal, would require $\frac{13 \times 1{,}000}{.85 \times 746 \times 10} = 2$ (prox.) pounds of coal per kilowatt hour, and deliver 500 watt hours per pound of coal; and these figures, actually attainable with existing steam dynamos for short periods under test conditions, are what should be compared with the record-making test of the pumping engine in your report.

| Steam per horse-power hour. Indicated. | Steam per horse-power hour. Effective. | Equivalent§ Coal per kilo-watt hours. | Equivalent Watt hours per lb. coal. |
|---|---|---|---|
| 11.22 | 13.4* | 1.8 | 557 |
| 13 | 15.3† | 2 | 500 |

Thus reduced, the question becomes one of accounting for the difference between results obtained by a high-class engine, running under test conditions, and those obtained by an entire station, under running conditions involving not only the decreased efficiency of the units under unfavorable load conditions, but all the standing losses of the station, inferior fuel, etc. The difference will be made up mainly from the following items:

1. Decreased boiler efficiency.
2. Lesser normal efficiency of engine.
3. Impaired conditions of engines.

*Calculated from water pumped against pressure.
†Electrical horse-power, 746 watts.
§Calculated on evaporation of 10 lbs. water per lb. coal.

4. Unfavorable engine load.
5. Leakage.
6. Condensation.
7. Auxiliaries.
8. Heating.

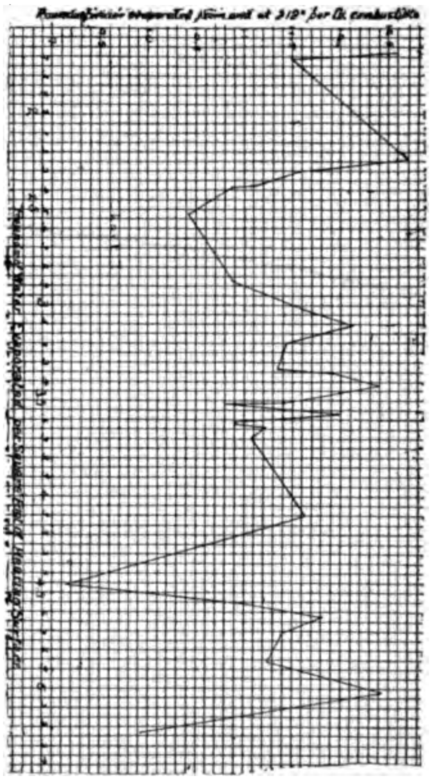

FIG. 1.

Much has been said of the disadvantage under which electric light stations labor on account of the wide difference between the minimum and the maximum loads, and thermal storage has been suggested as a means of evading this loss of efficiency. It is quite possible that this loss has been overestimated, so far as the boilers are concerned.

The capacity of a boiler is determined by the amount of water which it will evaporate in a given time; its efficiency, by the combustible required to evaporate a pound of water from and at 212°. To determine how the efficiency varied with the rate at which the boiler was run, within limits, I have plotted

FIG. 2.

on Figure 1 in the horizontal direction the water evaporated per hour per square foot of heating surface, and in the vertical direction the pounds of water evaporated from and at 212° per pound of combustible, as determined by 30 different tests on Babcock & Wilcox boilers. If there were any decided tendency

for the efficiency to follow the rate of evaporation within the range there covered, it might be expected to show itself here, but it will be seen that practically as good results are obtained at over five pounds per square foot of heating surface as at 1.75 pounds, and the intermediate tests show no dependence on the rate of evaporation. In Figure 2 I have plotted in the same way all the tests of which I could find a record, and in this wide range still no evidence is apparent of any dependence of the boilers represented on the rate of evaporation within the range covered. This means that the variation of efficiency of boilers within the range here comprised is less than the variations due to different firing, etc.

Wm. H. Bryan, in a paper read before the Engineers' Club, of St. Louis, gives the data and tests in which a battery of horizontal tubular boilers were forced to more than double their rating with only the following impairment of their efficiency:

| Coal per sq. ft. grate surface. | Coal per sq. ft. heating surface. | Water evaporated per sq. ft. heating surface. | Evaporation per lb. combustible from and at 212°. | Percentage of rated capacity. | Efficiency percentage of heat utilized. |
|---|---|---|---|---|---|
| 18.075 | .332 | 2.43 | 9.27 | 100.2 | 76.38 |
| 35.35 | .650 | 4.33 | 8.80 | 181.09 | 70.33 |
| 43.68 | .803 | 5.235 | 8.827 | 219.83 | 68.83 |

Here is a battery of boilers which were forced to nearly double their rated capacity with a decrease of only six per cent in their efficiency, and which could, doubtless, have been diminished to one-third of their rated capacity with a less impairment still. In other words, with good management and an adaptation to condition, these boilers would have taken care of a

maximum load six times the minimum without suffering extremely.

When a boiler is laid off completely, three methods may be followed:

1. The fire may be banked so completely that combustion is almost totally suspended, in which case the pressure will run down if the boiler is cut off from the main, and sufficient coal must be burned on starting to restore the heat lost by radiation and bring the boiler, contents and setting back to the running temperature.

2. The fire may be covered and the damper closed, but sufficient heat generated to keep up the pressure, in which case enough coal must be burned to supply the radiation loss.

3. The fires may be hauled and started new. In this case the half-burned fuel is sacrificed more or less, and much more labor involved.

It is when a boiler is thus practically laid off that it becomes a drag, the coal used in maintaining the fire in a condition to be started counting for nothing, so far as steam production is concerned. The engineer of a Philadelphia station, on a test made at my request, found that it required 1,200 pounds of buckwheat coal to keep up a pressure of 125 pounds on two water-tube boilers, having each fifty-nine square feet of grate surface. This was $\frac{1,200}{24 \times 2 \times 59} = .424$ pound per square foot of grate surface per hour.

A five days' test of a horizontal tubular boiler showed a consumption of .35 pound of coal per square foot of grate.

Another water-tube boiler in a five days' test used .5 of a pound per square foot of grate.

A Lancashire boiler with mechanical stokers used only .2 of a pound of coal per square foot of grate on a seven days' test.

Two other water-tube boilers, one on a seven days' test and the other on a test of several days' duration, used, respectively, .7 and .5 of a pound of coal per square foot of grate.

In each of these cases the boiler was shut off from the main and no steam nor water taken from it. The coal was used simply to maintain the pressure. A moderate rate of combustion is twelve pounds per square foot of grate per hour. Allowing .5 as the average consumption while standing, the coal burned by a boiler in this way would be 4.17 per cent of that burned while running at twelve pounds per square foot of grate for the same length of time.

If a boiler runs sixteen hours a day at an average rate of twelve pounds of coal per square foot of grate per hour, and stands the other eight with a consumption of .5 of a pound per square foot of grate per hour, the coal used, while idle, will be 2.04 per cent of the whole. If it runs half the time, the expense in coal, while standing, will be four per cent of the total amount. The following table gives the percentages for different lengths of running and different rates of combustion :

| Hours Running. | Hours Standing. | Percentage of Total Coal Used in Idle Boilers at .5 of a Pound per Square Foot of Grate While Idle. Average Rate Combustion per Square Foot Grate While Running. 12 | 15 | 18 | 20 | 24 |
|---|---|---|---|---|---|---|
| 23 | 1 | .18 | .15 | .12 | .11 | .10 |
| 22 | 2 | .33 | .30 | .25 | 23 | .19 |
| 21 | 3 | .59 | .47 | .40 | .36 | .28 |
| 20 | 4 | .83 | .66 | .55 | .50 | .41 |
| 19 | 5 | 1.08 | .87 | .66 | .65 | .55 |
| 18 | 6 | 1.37 | 1.10 | .92 | .83 | .69 |
| 17 | 7 | 1.69 | 1.35 | 1.13 | 1.02 | .85 |
| 16 | 8 | 2.04 | 1.63 | 1.37 | 1.23 | 1.03 |
| 15 | 9 | 2.44 | 1.92 | 1.64 | 1.48 | 1.23 |
| 14 | 10 | 2.89 | 2.33 | 1.99 | 1.75 | 1.44 |
| 13 | 11 | 3.40 | 2.73 | 2.30 | 2.07 | 1.70 |
| 12 | 12 | 4.00 | 3.23 | 2.70 | 2.44 | 2.04 |
| 11 | 13 | 4.69 | 3.79 | 3.18 | 2.87 | 2.40 |
| 10 | 14 | 5.51 | 4.46 | 3.75 | 3.38 | 2.83 |
| 9 | 15 | 6.50 | 5.26 | 4.42 | 4.00 | 3.35 |
| 8 | 16 | 7.69 | 6.25 | 5.26 | 4.76 | 3.85 |
| 7 | 17 | 9.19 | 7.41 | 5.96 | 5.79 | 4.87 |
| 6 | 18 | 11.11 | 9.09 | 7.69 | 6.98 | 5.88 |

It has been a matter of surprise, in following out this investigation, to find so moderate a difference between the performance of the boilers reported for long periods under widely varying capacities, and charged with all the coal used for banking, etc., and their normal efficiency under test conditions. This difference is shown in the following table, where the "test duty" is the best result obtainable under the best conditions with the fuel used; the "actual duty" is the number of pounds of water evaporated in a long term of service, divided by the coal used in the same period.

The third column is the ratio of the actual to the test efficiency, showing how badly the efficiency was impaired by the conditions of actual service.

With the exception of No. 11, the apparently low efficiency of which was due to a low grade of western coal, these results are surprisingly high.

| No. | Test Duty. | Actual Duty. | Ratio Actual to Test. | Per Cent Short of Standard. | Hours Run per day. |
|---|---|---|---|---|---|
| 1 | 8.58 | 8.009 | 94.5 | 19.91 | 24 |
| 2 | 8.68 | 7.302 | 84.1 | 26.98 | 6–12 |
| 3 | 9.96 | 8 02 | 8.05 | 19.8 | 24 |
| 4 | ..... | 7 5 | ..... | 25 | 24 |
| 5 | 10.5 | 9.96 | 94.6 | 4 | 23 |
| 6 | ..... | 10.00 | 95.24 | ..... | 24 |
| 7 | 7 | 6.14 | 87.71 | 38.6 | 24 |
| 8 | ..... | 6.04 | ..... | ..... | 14–20 Av., 17 |
| 9 | 11.2 | 9.83 | 87.71 | 12 | 24 |
| 10 | 10.8 | 9.85 | 97.72 | 8 | 24 |
| 11 | ..... | 5.75 | ..... | 42.5 | 24 |
| 12 | ..... | 11.36 | ..... | 13.60 | 24 |
| 13 | .... | 7.50 | ..... | 25.00 | 12 |
| 14 | ..... | 9.00 | ..... | 10.00 | 24 |

In comparing the duties attained in practice with the high standard established, it must not be forgotten that the standard was attained with one of the best steam coals procurable, with less than six per cent of ash-pit refuse. The results which we are comparing with this were obtained in many instances with coals having a much lower evaporative value per unit of weight, while their evaporative value per unit of cost may have been higher. Where the grate surface is ample, a very cheap grade of fuel can be used with a considerable reduction of the cost, and it is suggested that an economical advantage may arise from using two grades of fuel in plants that run long hours with widely varying loads; a good steaming coal with which the boilers can be forced at the time of overload, and a cheap small coal which can be used to advantage on the otherwise spare grate surface when the load is below the average. The fourth column of the table shows the percentage of difference between the results actually obtained and the standard, ten pounds of water per pound of coal, and is the percentage accounted for by the various causes affecting the boiler efficiency. The efficiency of the boiler

demands special consideration, for it affects directly the whole efficiency. Inefficiency in an engine affects only the steam which it uses, but inefficiency in a boiler affects the cost of all the steam produced for all purposes.

### IMPAIRED CONDITION OF ENGINE

In the exigencies of central station work, it is not possible always to keep an engine tuned up to its condition of maximum efficiency, and managers of stations will readily recognize that some of their units, if tested just as they are running, would, from one cause and another, fail to realize their best efficiency. Valves and pistons become worn and leaky, valve setting gets out of adjustment, stuffing boxes leak, not only wasting steam, but impairing the realized vacuum and increasing the work of the air-pump. Notwithstanding these derangements, the engine must be kept in commission, and its average efficiency for the year is sure to be below its maximum efficiency, as determined by a test when it is in its best possible condition. It is the average efficiency of many engines working under these disadvantages that we are comparing with the maximum efficiency of an engine to every detail of which expert attention had been given.

### ENGINE LOSSES DUE TO UNFAVORABLE LOAD

The performance that we have taken as a standard was accomplished at the load for which the engine was particularly adapted. The performance that we are comparing with it was accomplished under all sorts of conditions of over and under-loading. Figure 3 is given by Prof. R. C. Carpenter*

* The Variation in Economy of the Steam Engine Due to Variation in Load. Proceedings American Institute Electrical Engineers, Volume X, 1893.

as showing the rate of steam consumption that may be expected with engines of different types, and the method of variation of that rate with change of load.

These curves are based upon the steam consumption *per indicated horse-power*, but what we wish to know, not only for the purpose of comparison, but in order to handle the units of a station intelligently, is the rate of variation per kilowatt hour.

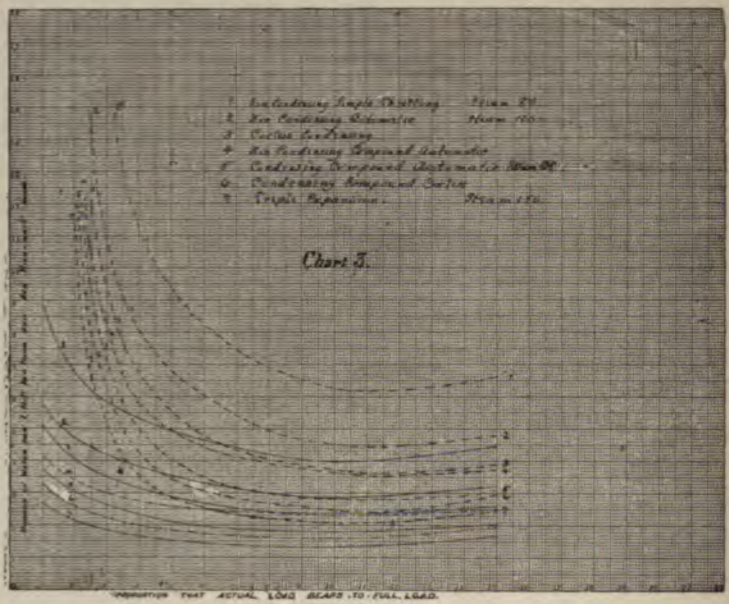


FIG. 3.

That the curve will be different from the indicated horse-power curve, is shown by Figure 4. The lower curve, is the first curve of Figure 3 re-drawn to a higher vertical scale. Assuming a difference at the best efficiency of fifteen per cent between the indicated and electrical horse-power, I have laid out the upper curve, showing the rate of variation on the same engine per kilowatt hour. At one hundred horse-power the engine takes forty pounds of steam

per hour per indicated horse-power, or $40 \times 100 = 4{,}000$ pounds per hour. But we only get eighty-five electrical horse-power out of it, so the cost per electrical horse-power is $\frac{40 \times 1{,}000}{85} = 47$ pounds, and the cost per kilowatt hour, $\frac{40 \times 100 \times 1{,}000}{85 \times 746} = 63$ pounds.

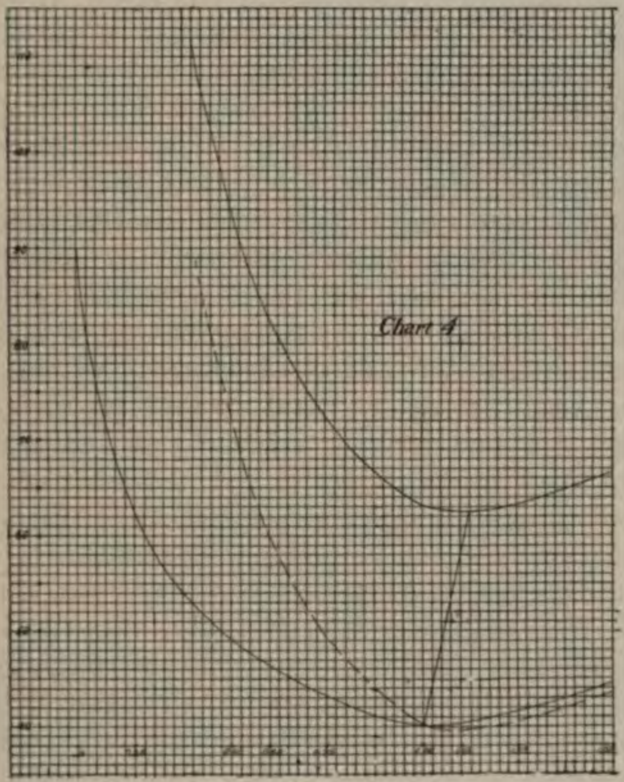


FIG. 4.

Calculating the other loads in the same way, the points for the upper curve were located. This curve is brought down to its dotted position for ready comparison with the other. Owing to the increasing proportion of the frictional and electrical losses, the

curve rises very rapidly with an under-load, while, as the load is increased, the diminishing ratio of these losses carries the point of minimum consumption further out, and it is seen that, while the steam rate per indicated horse-power is least at one hundred, the steam rate per kilowatt hour is least when the indicated horse-power is ten per cent greater, and the line rises less abruptly as the overload increases. It would seem as though every station manager would know the most efficient rate of output for each of his units, and how badly they suffered from a departure from this rate, but I found this to be in no wise the case.

The station that has a constantly changing load is at the worst disadvantage from inadaptability of units. The "load factor" proposed by Compton, expressed by the ratio of the area within the load-line to the area of the containing rectangle, is not a fair expression for this disadvantage; for of two stations, each having a "load factor" of sixty, for example, and one running six-tenths of the time on uniform load, as in Figure 5, and the other all the time on a constantly changing load, as in Figure 6, the first will be at a decided advantage in this respect. Its units, if adapted to their output, can be run at their maximum efficiency, and the station is better off even than a cotton mill, or other factory with a steady load, for it has a long run without interruption. It is to the fact that its load-line approximates more nearly this condition that the exceptional efficiency of the Brooklyn Edison No. 2 Station is due, and that an arc station is able to run at a less coal cost per unit of output. With a changing load like Figure 6, however, the units are at their maximum efficiency only momentarily, as at A, B, C, D. By plotting the engine blocks into the

actual load line as they are plotted into this conventional line, and as they have been in the actual load-line submitted from the Brooklyn station, it can be

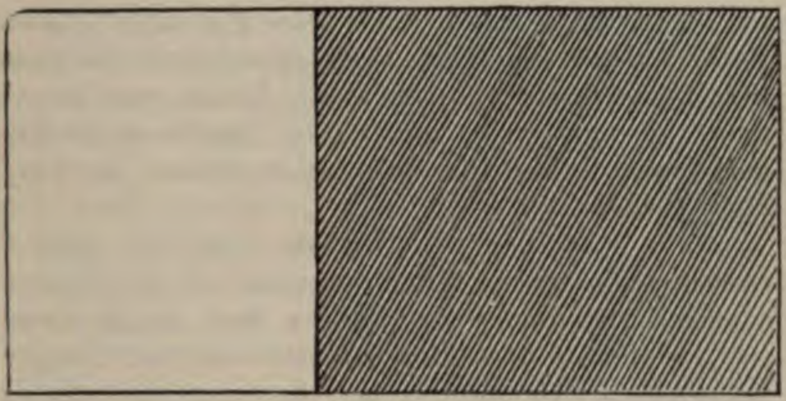

Fig. 5.

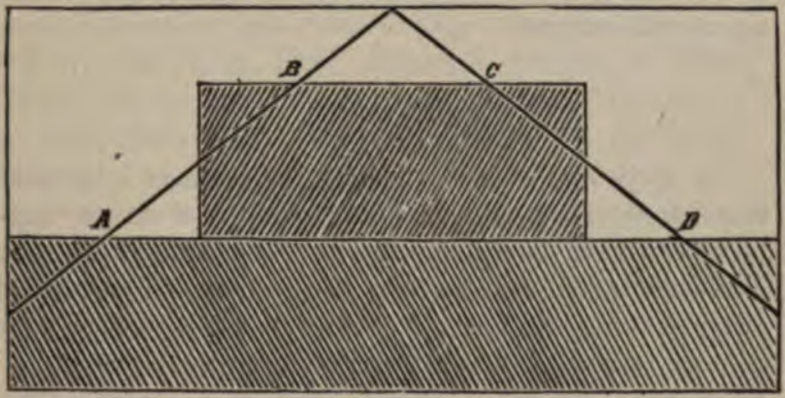


Fig. 6.

determined how much and for what proportion of the time they were under or overloaded, and from one of the consumption curves for the given type of

engine, the effect of such unfavorable loading may be estimated.

It is quite likely that the importance of the impairment of efficiency from this cause has been overestimated. Even on the steep kilowatt curve of the least efficient engine in Figure 4 it will be seen that if all the engines in the station run all the time at half load, the impairment would be less than thirty-three per cent, and if they ran all the time at fifty per cent overload, the impairment would be only *eight per cent.*

A. G. Pierce and R. S. Hale, who have made a careful study of the Boston stations of the Edison companies, say: "In our test we have finally found the variation due to causes which we first thought negligible, to be more than the variation due to change in load. As a matter of fact, the steam per indicated horse-power in our two 200 units holds within twelve per cent over a range from one-quarter up to full output."

## LEAKAGE

It is probable that the loss by leakage is greater than is generally supposed, and when the steam supposed to have been consumed is determined by the water-meter, leakage, either in the form of water or steam, counts against the engine. In a surface condensing plant, if there were no loss by blowing off or leakage, no water would have to be supplied to the system after it was once charged. As a matter of fact, a constant supply is necessary. At one of the stations visited the leaks were about 2,000 pounds per hour in the winter time, and in the summer, with one-half the engines, two-thirds the boilers and all the

heaters shut off, they were about 500 pounds per hour; in another they were 3,500 pounds per hour.

When it is remembered that, with the high-class engines which we are considering, thirteen pounds per hour represent a horse-power, it will be seen that this leakage may account for a considerable proportion of the difference between the ideal duty and that reported as actually attained. Some idea of the amount of leakage encountered in marine practice may be gleaned from a statement by D. E. Morrison, in a paper presented to the Liverpool Engineering Society, that, on a steamer having, on an average, 2,000 indicated horse-power, the fresh water added daily was five tons, or about one and one-half per cent of the total feed. This plant, he says, is exceptionally efficient, and cites another which required fresh water to the extent of 10.3 per cent. The trials of the "Iona", by the Research Committee of the Mechanical Engineers, showed that the quantity of water required to make up leakage was about six per cent of the total feed, although, beyond a slight leakage at the feed-pump gland during a portion of the trial, there was nothing apparent to the many observers which would account for such a loss. In this connection we may recall that a large amount of metered water is lost in the course of a year by blowing down the boilers, opening safety valves, testing water-gauges, etc.

## CONDENSATION

All the water evaporated by the boilers does not reach the engine in the form of steam, considerable being condensed in the conducting pipe. In a test this is allowed for and only the dry steam charged to the engine. Recent experiments have shown that each

square foot of bare pipe exposed under average conditions will condense .85 of a pound of steam per hour. It would take at this rate only fifteen square feet to consume a horse-power (*i. e.*, thirteen pounds of steam). Even when covered with a non-conducting material, this loss is considerable, when it is considered that not only the pipe, but all heated surfaces, are contributing to it. If we allow the surfaces only one fifth of this on an average, on account of many of them being covered, we shall still lose one of our standard horse-powers for every seventy-five square feet of steam-containing surface.

Some conception of the combined losses, due to leakage and condensation, may be gathered by imagining, or, better still, if practicable, actually trying the experiment of keeping the plant under steam at running pressure with the engines turned on, but not running, and weighing the amount of coal burned per hour to keep up the pressure under these conditions. The indications are that it will furnish in many plants a surprisingly large percentage of the total coal consumed.

## AUXILIARIES

A large amount of steam is used by the auxiliary engines about a station. While it is true that the boiler feed pumps, for instance, develop little power as compared with that of the main engines which they supply, they are, as a rule, very extravagant in the use of steam. The same thing is true of the ordinary independent air and circulating-pump. There are also in many stations small engines used for operating automatic stokers, fans for artificial draft, coal-handling machinery, etc., the aggregate steam consumption reaching a very considerable figure. The steam connections to these auxiliaries add very materially to the

complexity of the piping system and increase the leakage and condensation losses. There is a movement in the direction of replacing steam-operated auxiliaries by those operated by electric motors, reducing the piping system to the utmost simplicity. At a cost of, say, twenty pounds of steam per indicated horse-power, and a loss of fifty per cent in its electrical transmission and re-development, one would have, at the point of application, only forty pounds of steam per effective horse-power, against the seventy-five or 200 pounds required by the steam motors, displaced, to say nothing of the reduction to be expected in the radiation and leakage losses.

### HEATING

The heating of the station usually follows from the unavoidable radiation, but the offices, and often considerable other space, are heated by exhaust steam at the expense of back pressure upon the engines, or by live steam from the boilers direct. Either of these, while necessary, is a drag on the efficiency of the station in kilowatt hours per pound of coal.

### STARTING ENGINES

No inconsiderable amount of steam is used in getting a large engine ready to put to work and allowing it to "turn over" slowly for some time, as is often done before it gets its load. One manager assures me that a careful computation showed the cost of starting up a large engine, including the labor, oil, etc., as well as the steam required, to be over three dollars.

In the following table, I have undertaken to show, for the few stations from which reliable data have

been procurable, the proportions which the various demands upon the coal pile bear to each other and to the whole. The column headed "efficiency" shows the percentage of the coal actually used that would have been used by the standard equipment (10 pounds of steam per hour and the electrical horse-power .85 of the indicated). Under "engines" is the percentage of the total coal consumed by reason of the lesser efficiency of the engines; under "conversion", the percentage of the coal consumed by reason of the conversion losses exceeding the standard. The next three columns give the percentage of the total coal used to supply leakage, condensation and auxiliaries. The column under "boilers" gives the percentage by which the consumption was affected, by reason of the fact that the boilers evaporated more or less than ten pounds of water per pound of coal, while the column of "unassigned" gives the aggregate of all the losses not separately reported.

| No. | Hours Run. | Results. | | Efficiency per cent. | Percentage of Coal Used for | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lbs. coal per kilow't hour. | Watt hours per lb. coal. | | Engines. | Conversion. | Leakage. | Radiation. | Auxiliaries. | Boilers. | Unassigned. |
| 1 | 24 | 8.30 | 120.5 | 24.09 | 20.95 | .24 | .... | .... | .... | 19.91 | 34.79 |
| 2 | 6–12 | 6.24 | 160.3 | 32.05 | 27.30 | 3.63 | .... | .... | .... | 26.98 | 10.04 |
| 3 | 24 | 3.71 | 269.5 | 53.91 | 9.03 | .... | 11.63 | .... | ... | 19.98 | 5.45 |
| 4 | 24 | 4.56 | 219.7 | 43.86 | 5.88 | 2.13 | <—12 | —> | .... | 25.00 | 23.11 |
| 5 | 23 | 8.69 | 115.1 | 23.01 | 24.97 | 6.95 | .... | .... | .... | .4 | 32.66 |
| 6 | 24 | 3.82 | 262. | 52.10 | 8.80 | 5.03 | .... | 4.00 | .... | .... | 30.07 |
| 7 | 24 | 8.91 | 112.2 | 22.45 | 22.56 | 5.50 | .... | ... | .... | 38.60 | 10.89 |
| 8 | 14–20 Av 17 | 8.67 | 115.3 | 23.07 | .... | .... | .... | .... | 6.04 | 39.60 | 31.28 |
| 9 | 24 | 6.64 | 150.6 | 30.12 | 30.12 | 21.50 | .... | .... | .... | 1.70 | 17.56 |
| 10 | 24 | 8.62 | 116. | 23.20 | 24.12 | 7.5 | .... | .... | .... | 1.50 | 43.67 |
| 11 | 24 | 10.13 | 98.7 | 19.74 | 9.27 | .... | .... | .... | .... | 42 50 | 28.49 |
| 12 | 24 | 7.45 | 134.3 | 26.85 | 38.22 | .... | .... | .... | .... | -13.60 | 48.53 |
| 13 | 12 | 7.33 | 136.5 | 27.29 | 11.45 | .... | .... | .... | .... | 25.00 | 36.26 |
| 14 | 24 | 5.68 | 176.2 | 35.21 | 10.64 | 1.07 | .... | .... | 5.30 | 10.00 | 37.77 |

## STATION NO. 1

Incandescent, run 24 hours per day.

Average daily output, 13,600 kilowatt hours.

Coal per kilowatt hour, 8.3 pounds.

Watt hours per pound of coal, 120.5.

Boilers: Water-tube.

Average evaporation per pound of coal, 8 pounds.

Average feed-water temperature, 212 degrees.

Average boiler pressure, 125 pounds.

Coal: Buckwheat.

Engines: Vertical, compound non-condensing, four-valve, direct-connected.

Water per hour per indicated horse-power, at best efficiency, 25.8 pounds.

Water per kilowatt hour, at best efficiency, 37.5 pounds.

Generators: General Electric.

## STATION NO. 2

Incandescent, run 6 to 12 hours per day.

Average daily output, 1,400 kilowatt hours.

Coal per kilowatt hours, 6.24 pounds.

Watt hours per pound of coal, 160.4.

Boilers: Water-tube.

Average evaporation per pound of coal, 7.3.

Average feed-water temperature, 212.

Average boiler pressure, 125 pounds.

Coal: Buckwheat.

Engines: Horizontal, cross-compound condensing, high-speed, single-valve, automatic, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 25.7.

Water per kilowatt hour, at best efficiency, 39.3.
Generators: General Electric.

STATION NO. 3

Incandescent, run 24 hours per day.
Coal per kilowatt hour, 3.71.
Watt hours per pound of coal, 269.5.
Boilers: Water tube.
Average evaporation per pound of coal, 8 pounds.
Engines: Vertical, compound condensing, four-valve direct-connected.
Water per hour per indicated horse-power, at best efficiency, 15.5.
Generators: General Electric.

STATION NO. 4

Incandescent, run 24 hours per day.
Average daily output, 200,000 kilowatt hours.
Coal per kilowatt hour, 4.56 pounds.
Watt hours per pound of coal, 219.7.
Boilers: Water-tube.
Average evaporation per pound of coal, 7.5 pounds.
Average boiler pressure, 160 pounds.
Coal: New River and hard screenings.
Engines: Vertical, triple-expansion, four-valve, direct-connected.
Water per hour per indicated horse-power, at best efficiency, 15.
Water per kilowatt hour, at best efficiency, 23.5.
Generators: General Electric.

STATION NO. 5

Arc and Incandescent, run 24 hours per day.
Average daily output, 15,600 kilowatt hours.

Coal per kilowatt hour, 8.69 pounds.

Watt hours per pound of coal, 115.1.

Boilers: Return tubular.

Average evaporation per pound of coal, 9.96.

Average feed-water temperature, 208.

Average boiler pressure, 125 pounds.

Coal: Bituminous, 2 parts; screenings, 1 part.

Engines: Simple non-condensing, belted to generators; compound non-condensing, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 29.1.

Water per kilowatt hour, at best efficiency, 47.7.

Generators: General Electric, Thomson-Houston.

STATION NO. 6

Incandescent, run 24 hours per day.

Average daily output, 6,500 kilowatt hours.

Coal per kilowatt hour, 3.82 pounds.

Watt hours per pound of coal, 262.

Boilers: Return tubular.

Engines: Compound condensing, four valve, belted to countershaft.

Water per kilowatt hour, per indicated horse-power, 15.5.

STATION NO. 7

Incandescent, run 24 hours per day.

Average daily output, 13,000 kilowatt hours.

Coal per kilowatt hour, 8.91 pounds.

Watt hours per pound of coal, 112.2.

Boilers: Water-tube.

Average evaporation per pound of coal, 6.1.

Average feed-water temperature, 180.

Average boiler pressure, 135 pounds.

Coal: Anthracite pea.

Engines: Simple non-condensing, belted to generators; compound non-condensing, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 28.

Water per kilowatt hour, at best efficiency, 45.

Generators: Bi-polar.

STATION NO. 8

Arc and incandescent, run 14 to 20 hours per day, averaging 17.

Average daily output, 12,400 kilowatt hours.

Coal per kilowatt hour, 8.67.

Watt hours per pound of coal, 115.3

Boilers: Water-tube.

Average evaporation per pound of coal, 6 pounds.

Average boiler pressure, 160 pounds.

Coal: Kentucky slack.

Engines: Cross-compound condensing, direct-connected; tandem compound, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 28.

Water per kilowatt hour, at best efficiency, 45.

Generators: Westinghouse, General Electric and Wood.

STATION NO. 9

Arc and incandescent, run 24 hours per day

Average daily output, 2,700 kilowatt hours.

Coal per kilowatt hour, 6.64 pounds.

Watt hours per pound of coal, 150.6.

Boilers: Horizontal, tubular and water-tube.

Average evaporation per pound of coal, 9.83.

Average feed-water temperature, 140.

Average boiler pressure, 120 pounds.

Coal: Clearfield and coal dust, one-half each.

Engines: Single-acting, compound condensing, belted to generators. Simple, automatic, high-speed, non-condensing, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 28.

Water per kilowatt hour, at best efficiency, 53.27.

Generators: Westinghouse, Thomson–Houston and General Electric.

STATION NO. 10

Arc and incandescent, run 24 hours per day.

Average daily output, 3,400 kilowatt hours.

Coal per kilowatt hour, 8.62 pounds.

Watt hours per pound of coal, 116.

Boilers: Horizontal, tubular and water-tube.

Average evaporation per pound of coal, 9.85.

Average boiler pressure, 112 pounds.

Coal: Bituminous, 4 parts; Yars screenings, 1 part.

Engines: Compound condensing and simple non-condensing, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 28.5 pounds.

Water per kilowatt hour, at best efficiency, 38.1.

STATION NO. 11

Arc and incandescent, run 24 hours per day

Average daily output, 4,000 kilowatt hours.

Coal per kilowatt hour, 10.13 pounds.

Watt hours per pound of coal, 98.7.

Boilers: Horizontal, tubular and water-tube.

Average evaporation per pound of coal, 5.75 pounds.

Average feed-water temperature, 212.

Average boiler pressure, 115.

Coal: Screenings.

Engines: compound condensing, belted to generators; compound condensing, belted to countershaft.

Water per hour per indicated horse-power, at best efficiency, 22 pounds.

Water per kilowatt hour, at best efficiency.

STATION NO. 12

Incandescent, run 24 hours per day.

Average daily output, 4,300 kilowatt hours.

Coal per kilowatt hour, 7.45 pounds.

Watt hours per pound of coal, 134.3.

Boilers: Horizontal, tubular.

Average evaporation per pound of coal, 11.36 pounds.

Engines: Four-valve, simple; single-acting, compound; single-acting, simple.

Water per hour per indicated horse-power, at best efficiency, 34.3 pounds.

STATION NO. 13

Incandescent, run 12 hours per day.

Average daily output, 5,000 kilowatt hours.

Coal per kilowatt hour, 7.33 pounds.

Watt hours per pound of coal, 136.5.

Boilers: Horizontal, tubular.

Engines: Tandem compound, four-valve, condensing.

Water per hour per indicated horse-power, at best efficiency, 20 pounds.

STATION NO. 14

Arc and incandescent, run 24 hours per day.

Average daily output, 124,000 kilowatt hours.

Coal per kilowatt hour, 5.68 pounds.

Watt hours per pound of coal, 176.2

Boilers: Horizontal, tubular.

Average evaporation per pound of coal, 9 pounds.

Average feed-water temperature, 120.

Average boiler pressure, 115 pounds.

Coal: Tennessee, run of mine.

Engines: Tandem compound condensing, belted to jackshaft; double tandem compound, non-condensing, belted to jackshaft; cross-compound, belted to generators.

Water per hour per indicated horse-power, at best efficiency, 17.5 pounds.

Water per kilowatt hour, at best efficiency, 26.65 pounds.

Generators: Thomson–Houston, Eddy, Wood and Detroit.

F. R. Low.

DISCUSSION

Mr. Swetland: I wish to say further, in presenting this report, that I feel that, during the six years that this work has been in my hands, there has been, perhaps, some good work done for the association. We have, I am sure, in some cases, stimulated an exertion to better work. I do feel, however, that the work has not produced the results, and this report does not show the results, which I hoped to present to you. There is this to contend with in the work: In the first place, the station manager does not like to have his private work laid before the public, and I feel that in a public convention of this kind we can not get for distribution such a report as can be obtained by associations where the work is more private, as, perhaps, the Edison organization. It seems

to me, therefore, that the conduct of this work in future would perhaps be better if confined entirely to the hands of the secretary, letting him secure such information as can be obtained by correspondence, without any further expense to the association.

I desire to thank the members for their co-operation in the work, and I feel that they have done all that could be expected; and, for my part, I have done my best to serve you. Mr. President, perhaps it is not necessary to read the report.

THE PRESIDENT: No, I think it is unnecessary, Mr. Swetland, because it has been in the hands of every active member for some weeks past.

I think it is my duty to advise the association of the very great interest that has been taken this year, by Mr. Swetland, in the preparation of this report. We have had several interviews. He has visited me at my home in Toronto, and I have made several trips to New York to visit him, in connection with other association matters, and we have tried to devise a plan whereby we could make this report much more interesting than ever before. We appreciated the fact that if you ask people to do anything voluntarily it is sometimes apt to be neglected, and so we decided, in our efforts to make this report appear before our members in a manner that would be satisfactory to us, to engage an expert gentleman to visit the different central stations, to secure and give this information at first hands. However, while I think we have a much more interesting report than we have had in the past, it is not satisfactory, and I doubt very much the wisdom of continuing this particular committee. The central station managers (and I can hardly blame them) are more or less diffident about giving to this association the information—the actual private informa-

tion—as to costs, maintenance, etc., with which only can it be as valuable as such a report should be. However, the matter is in your hands. If some gentleman that is acquainted with the work of the committee will move for its discharge or for its retention, either one way or the other, the question will be taken up.

A Member: I move that the committee be discharged.

Mr. Beggs: I should like to add to that, Mr. President, that the work the committee has heretofore done devolve upon the secretary of the association, as has been so well suggested by the chairman of that committee. If you recollect, I urged this course a year ago. I felt that this was work that ought naturally to go to the secretary's office. In his official capacity, much of these data could be obtained during the year. Therefore, I would suggest that the duties of the committee be dispensed with, and that they devolve upon the secretary of the association instead of upon a special committee.

The President: You have heard the resolution, gentlemen, to discharge the committee. Is it your pleasure that that committee be discharged?

Carried unanimously.

Mr. Ayer: I want to offer thanks to the chairman of that committee, who has served this association so faithfully in that capacity. There are few who realize how much Mr. Swetland has done in that direction, except those that have been associated with him. I do not think it necessary to speak on that.

Judge Armstrong: I was very sorry, Mr. President, to see the committee discharged, only for the reason that we are dispensing with the services of Mr. Swetland, which he has given us for several years in

this capacity, and the report of this committee has invariably been of great value. He has always lamented that he could not make it perfect because of the difficulties referred to here in his report; but he has given us every year and at every convention very valuable information; and while I acquiesce in his suggestion, in the suggestion of the chair and in the suggestion of the gentleman who made the motion, I do so with regret, and am very happy to join in an expression of our thanks—not merely perfunctorily, but our real thanks—to Mr. Swetland for what he has done for us.

THE PRESIDENT: It has been moved by ex-President Ayer and seconded by ex-President Armstrong that the thanks of the association be tendered to Mr. H. M. Swetland, chairman of the Committee on Data, for the work that he has done for the association in the past. Is it your pleasure that the motion carry?

Carried.

THE PRESIDENT: Mr. Swetland, it gives me, as the retiring president, particular pleasure to be able to advise you of this motion that has been unanimously carried. I think that I know more, perhaps, than any one else the self-sacrificing work that you have done during the past year, and I am quite sure that this vote of thanks to you is genuine and sympathetic on behalf of the members of the association.

THE PRESIDENT: The next report is that of the Committee on Standard Electrical Rules, Captain William Brophy, chairman.

CAPTAIN BROPHY: It was only last Saturday that the committee of which I was a member, to formulate and amend the national code, held its last meeting. My report could not be written until after that. It is now in the hands of the typewriter, and will be ready in the afternoon.

THE PRESIDENT: You wish to defer the presentation of your report until this afternoon, Captain?

CAPTAIN BROPHY: Until this afternoon's session.

THE PRESIDENT: I think we have time before us, and I will ask the chairman of the finance committee, Mr. John A. Seely, if he is ready to present his report.

MR. SEELY: I am ready, Mr. President.

THE PRESIDENT: We shall be very pleased to have you report now, Mr. Seely. I should like you to come forward, because I am sure all those members who have not already seen you are very anxious to have a glimpse of you.

MR. SEELY: Thank you, Mr. President.

Mr. Seely then read his report as follows:

## FINANCIAL REPORT FOR YEAR 1896

### RECEIPTS

| | | |
|---|---|---|
| Active membership dues for the year 1896 | $2,550 00 | |
| Active membership dues for the year 1897 | 150 00 | |
| Associate membership dues for year 1896 | 1,590 00 | |
| | | $4,290 00 |
| National Electrical Exposition Company | $2,000 00 | |
| Sale of Report of Nineteenth Convention | 350 00 | |
| Sale of badges | 143 00 | |
| Sale of publications | 22 00 | |
| Advertisements in proceedings | 180 00 | |
| | | 2,695 00 |
| Total receipts | | $6,985 00 |
| Balance in bank January 1, 1896 | $716 90 | |
| Balance in petty cash January 1, 1896 | 21 75 | |
| | | 738 65 |
| | | $7,723 65 |

### DISBURSEMENTS

| | | |
|---|---|---|
| Salary of Secretary | $2,000 00 | |
| Rent | 401 20 | |
| Furniture | 165 00 | |
| Printing and stationery (including proceedings and papers read at meetings) | 2,143 34 | |

| | | |
|---|---|---|
| Entertainment | $69 05 | |
| Testimonials | 50 00 | |
| Sundry expenses | 31 08 | |
| Rebate to associate members | 10 00 | |
| Stenography and typewriting (including report of convention) | 1,018 28 | |
| Traveling expenses | 153 11 | |
| Badges | 204 74 | |
| Postage and telegrams | 91 91 | |
| | | $6,337 71 |
| Balance January 1, 1896 | | $1,385 94 |
| Balance in bank January 1, 1896 | $1,446 23 | |
| Debit to petty cash January 1, 1896 | 60 29 | |
| Net balance | $1,385 94 | |

ASSETS

| | | |
|---|---|---|
| Cash as per above statement | $1,385 94 | |
| Cash in hands of Finance Committee | 889 29 | |
| Office furniture, as appraised by Finance Committee | 297 00 | |
| | | $2,572 23 |

LIABILITIES

None

The President: I am sure, gentlemen, that you must all be satisfied with the present showing of the finances of the association. We have absolutely no liabilities. We have surplus assets amounting to over $2,500. It is only a year or two since that we were rather heavily in debt, and were calling upon certain of the liberal members of the association to help make up the deficit. The association has got a fair start now; and while I do not see the advantage, in an association of this kind, of accumulating a large fund or a credit balance, I am gratified to think that the association is in such shape that if any opportunity for good work arises to help onward our interests for the benefit of the active members—the central station members—we have the wherewithal with which to undertake such work.

There are a few announcements that I should like to make before I declare this meeting adjourned. Before doing so, I should like to afford an opportunity to any members who have any matters that they wish to bring before the meeting, or that they would like to notify the chair of their intention to bring before any subsequent meeting of the association.

MR. SEELY: Mr. President, I desire to give notice to the chair that I shall move to change the by-laws to the effect that the retiring presidents shall all become honorary members of the association.

THE PRESIDENT: I will let that stand as a notice of motion, Mr. Seely. Has any other member anything about which he wishes to notify the chair?

## ANNOUNCEMENTS

The President: The secretary has asked me to request the members to turn in their railroad certificates to the secretary's office, in order that they may be properly indorsed, so that the member owning a certificate will be enabled to secure the reduced rate when purchasing his return fare.

I have also been asked to announce that the books of coupon tickets, for various excursions in the neighborhood of the Falls, are for sale at the secretary's office. The price is one dollar. The ordinary fare for the various trips amounts to $2.85. The coupon tickets include a trip of about thirteen miles on the Canadian side of the river, to Lewiston, the Falls and Chippewa; include the trip down the Gorge road, a trip up the Tower, on the "Maid of the Mist,' across Suspension Bridge, across the ferry at Lewiston, and other attractions. The association has made such arrangement on behalf of the members that we are enabled to offer these coupon books for one dollar, the regular fare being $2.85.

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If there is no other business to come before the meeting, a motion to adjourn until 2.30 o'clock this afternoon will be in order.

On motion of Judge Armstrong, seconded by Mr. Ayer, the convention took a recess until 2.30 p. m.

## SECOND SESSION

President Nicholls called the convention to order at 2.30 p. m.

# ANNOUNCEMENTS

THE PRESIDENT: Gentlemen, I have to announce that after the close of this afternoon's session we intend to proceed to the power-house of the Niagara Falls Power Company. We have an invitation, and they will be expecting us between five and six o'clock; so that, immediately after the close of the meeting this afternoon, those of the delegates who wish to inspect the great developments of the Niagara Falls power will have an opportunity to do so.

I might also announce that we intend to accept the invitation extended to us by the Carborundum Company, to visit their works at the close of the session to-morrow afternoon. The process is very interesting, and I am sure the visit will be one of both pleasure and profit to every member, and I hope every one will make a point of being present when we visit the Carborundum Company's works.

The secretary has handed me a letter, dated June 2d, signed by the Erie Gas Engine Company. I will read it and refer it to the association, to take such action upon it as they may deem proper. The names of several companies are mentioned in the letter, but I do not think it my province to mention them here.

"June 2d, 1897.

"National Electric Light Association,
"New York city, N. Y.

"GENTLEMEN: A technical paper devoted to the electrical trade, and a paper devoted to the gas

trade, have, for the last several weeks, contained very broad assertions complaining of the indisposition of gas-engine manufacturers to give the profession data in regard to gas engines. We have not cared to ventilate our views in journals whose verdict has thus been rendered in advance in this manner, but have preferred to contradict their unfounded assertions at the proper time and in the most effective manner, and it occurs to us that the proper time and the most effective manner is the meeting of your association, to be held next week at the Falls.

"Our gas engine is made in Erie, Pa., which is one hundred miles from the Falls, and is, therefore, extremely convenient, express trains running frequently both ways to make the trip in a couple of hours.

"We therefore have pleasure in herewith inviting your body to send a committee of, say, five or six of your most eminent and thorough members to make as critical inspection and test as may be necessary to enable them to acquire any data in reference to gas engines which the profession is, or feels itself, in need of.

"We shall be pleased to place at your disposal, for testing purposes, single-cylinder engines, as well as twin-cylinder engines, in connection with both shunt-wound and compound-wound dynamos, and shall be pleased to place at your disposal, at the same time, both artificial and natural gas, so that comparisons of the capacity of the engines can be made with different kinds of gas. We shall have Schaeffer and Budenberg tachometers and indicators, Weston recording ammeters and voltmeters, for the purpose of enabling your committee to obtain data, and should be pleased were any of the committee to bring with them Bristol recording ammeters and voltmeters in addition. We believe that in this way, and with a committee of five or six men, there could be, under these circumstances, the most thorough test made of gas engines which has thus far, to our knowledge, been made, at least from the standpoint of ability to produce current; and as there are, in the city of

Erie, Backus engines, as well as Otto engines, the owners of which would doubtless be willing to have them tested, it will be seen that comparative results can, at the same time, be obtained.

"We should be pleased to pay the expenses of said committee from the Falls to Erie and return, and beg to assure them in advance that if our invitation is accepted they will be well taken care of. We make no requirements in the case as a condition precedent of the acceptance of our invitation, except that the committee make its report, in accordance with the facts, to your honorable body, and that a copy of said report be given us by your committee at the same time that the original report is sent in to your body.

"We trust you will accept this invitation, both in the interest of knowledge, as well as to enable us to demonstrate to the readers of the journals referred to that there is one gas-engine company that has both the ability and the disposition to furnish data to such people as know what data they want.

"Yours truly,

"ERIE GAS-ENGINE COMPANY,

"Manufacturers 'Climax' Gas Engine,

"MAX H. C. BROMBACHER,

"Eastern Representative."

THE PRESIDENT: Has any one any motion to make in reference to this?

MR. AYER: Mr. President, if anything of that nature is in order, I think we have among our associate membership here a large delegation who would like to prepare similar invitations and offer the articles of their product for test. I think that a motion is in order that the letter be laid on the table.

THE PRESIDENT: Gentlemen, it has been moved by Mr. Ayer that the communication be laid on the table. Is it your pleasure that the motion be declared carried?

Carried.

THE PRESIDENT: Before we proceed with the regular business of the convention, I might say that there are some gentlemen here, with the object of inviting the association to meet at Omaha, Nebraska, and at Indianapolis, Indiana. There is also a letter from the executive office of the Trans-Mississippi and International Exposition, of Omaha, Nebraska, dated May 25th, addressed to the National Electric Light Association. It reads as follows:

"OMAHA, NEB., May 25th, 1897.

"National Electric Light Association,
"In Convention Assembled at Niagara, N. Y.

"I take pleasure, through our Commissioner of Electricity, Prof. R. B. Owens, in extending to your association a cordial invitation to hold its annual meeting, in 1898, in the city of Omaha, Neb. I beg to call your attention to the fact that a great, exposition of the arts, industries and civilization of the trans-Mississippi country will be held in this city from June 1st to November 1st, 1898. This exposition will celebrate no centennial in the history of this country, but will fittingly commemorate the close of the first half century of its history—a period teeming with great events, one of the greatest of which has been the building of a mighty empire of twenty-four States and territories west of the Mississippi River.

"During this period of development, the greatest achievement of science has been in the field of electricity, and at this exposition no small part will be devoted to electricity.

"We invite you to this beautiful city next year. and tender to you the free use of an auditorium for your deliberations. We ask you to come to the gateway of the trans-Mississippi country, where the product of the best thought and inventive genius in all departments of electricity will be on exhibition.

"Yours truly,

"GORDON W. WATTLES,

"President."

THE PRESIDENT: I believe Professor Owens is in the room. I therefore have much pleasure in extending to him an invitation to address the convention, briefly, in favor of Omaha as our next meeting place.

PROFESSOR OWENS: Mr. President and Gentlemen, I believe it has been some years since the association has held an annual meeting in the West—some five years, I believe, or will be at that time. I believe that Omaha will offer exceptional facilities next year for holding such a meeting as the annual meeting of this association. I believe the membership in the West will be strengthened. I know the geographical center is about Omaha; not of the membership, however. As stated in President Wattles's letter, it will be attempted to make electricity the feature of this exposition. Those manufacturers who have been communicated with have signified their willingness, and desire to participate largely in this exposition. The railroad rates will be exceptionally good. Omaha is only one night's ride from Chicago, and the authorities of both the exposition and the city of Omaha will extend every courtesy to the association if you will do us the honor to come to Omaha at that time.

THE PRESIDENT: Mr. Evans Woollen, a gentleman from Indianapolis, is here to represent the claims of

that city. If he is in the room, I should like to accord him the same courtesy.

MR. WOOLLEN: I thank you, Mr. President. My first promise, gentlemen, is that I will not take more than a minute and a half or two minutes of your time. Admiral Brown, when he was retired from the navy a week or two since, announced that he intended to spend the rest of his life in the most beautiful city of America. It is to that city that we have been sent to invite you to come for your next meeting. We were sent—my colleague, Mr. Perry, and myself—by the Commercial Club of Indianapolis, whose membership includes 1,000 business and professional men, and whose bank account justifies our promises. The promises that we make you are not made irresponsibly. We were instructed by the club's board of directors to promise you that if we are honored by the acceptance of our invitation, your comfort and pleasure will be provided for adequately. You may ask the sound-money democrats how their convention was entertained last January; and I am assured by Mr. Perry, my colleague here, the secretary and treasurer of our light and power company, that we can also promise you an exhibition of one of the best central stations in the country. There are three facts, gentlemen, to which I wish to call your attention: First, that, according to the census of 1890, the exact center of population of the United States is twenty-three or twenty-four miles from Indianapolis; second, that sixteen competing railway lines radiate, spoke-like, from our Union station, and, third, that four hotels of the first class afford metropolitan accommodations for at least 2,500 guests. We want you, gentlemen. Two of us have come several hundred miles to tell you how much we want you. We want you, not for

the money that you will spend in Indianapolis, but we want you there that we may know you, and that you may know us and our beautiful city. We want you for the good things that we know you will say about us after you have experienced our hospitality. I thank you.

VICE-PRESIDENT CLAY: Mr. President, I am sure each delegate here appreciates the kindly spirit that has prompted these invitations for the association to meet at these respective places. There was also a communication presented this morning extending a similar invitation from the city of Nashville, Tennessee. I believe that it will hardly be possible for this convention to select from among these three invitations the one that we should accept, and I therefore move you that the invitations be referred to the executive committee.

THE PRESIDENT: It is moved and seconded that, as is usual, the invitations be referred to the executive committee to be acted upon. Is it your pleasure that the motion carry?

Carried.

THE PRESIDENT: I might say here that a photograph of the delegates will be taken immediately after the close of the session to-morrow morning.

Invitations to Mr. Stillwell's lecture, to be held in the Park Pavilion to-morrow evening, can be had upon application to the secretary.

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THE PRESIDENT: I have much pleasure in calling upon Mr. Cahoon, of Elmira, New York, to read his paper, entitled "The Establishment of a Base Price for Current," a very attractive title and most interesting subject.

# THE ESTABLISHMENT OF A BASE PRICE FOR CURRENT

NOTES ON CENTRAL STATION DATA

If we omit stations in the larger cities, where the population is concentrated, and let our minds wander over the general run of stations situated throughout the United States, how many of these, if they were asked the question, "Does incandescent lighting pay?" could answer the question affirmatively? Suppose the stations that are at present supplying their respective cities and towns with arc lights should have this source of revenue taken away from them, what would be the result? Could they survive upon the incandescent lighting that they do, combined with the power that they furnish for stationary motors? I think we may safely answer, No. The money-earning factor of the station would have disappeared; there would remain but the chaff. From one quarter and another we hear rumors of this and that town deciding that they think it is for their best interests to become owners of their own electric light plants for lighting their streets; and no electric light station exists at present but is subject to this menace; a turn of the wheel may bring them face to face with a crisis of this kind any day. The stations were built in good faith and the owners expect to obtain a fair return for their investment; such returns at the present time come largely from the fact that they have a contract with the city for arc lights, which yields them a good revenue and a fair profit on their investment, and in many cases the arc lighting is the only

branch of the station that really pays, and upon it is thrust the burden of carrying the whole company. The incandescent lighting either does not pay expenses, or just barely does so, while in a great many stations the amount of power sent out over the lines for the operation of stationary motors is not enough to count as a very serious factor in the operating receipts or expenses. To bring incandescent lighting up to as profitable a basis as arc lighting is a serious problem, now that the people are accustomed to obtaining incandescent lights so cheaply, and certainly some stations are so situated that they can not do it; others can by making a fight for it. Certain classes of stations are still giving flat rates in many instances, and the solution of the problem for them is to change over to meters and make the meter price one that will be equitable, both to the company and to the consumer. Where the charge has been too high, there will be, of course, no opposition encountered to a reduction, and in such cases it will be necessary for each company to study the situation carefully and see whether it is wise for them to continue charging the high rate or to change over to a just rate, founded on a substantial basis, and give the customer the benefit of the reduction. In such cases it is a question as to what is the best policy for the company to pursue. If it be decided that it is good policy to make a reduction to an equitable rate, then on what basis shall the company work? The thought has occurred to me, that it might be wise for the convention to adopt what may be called a standard rate, based on some factor or factors that will admit of application to every station in the country.

A careful analysis of the prices paid per kilowatt hour for incandescent light in different sections of the

country, seems to show that, in many instances, prices charged are based upon what somebody else has charged, rather than on what ought to be charged in view of the cost of the principal items entering into the operating expenses at each particular place. The two main factors that enter into operating expenses are wages and coal. If we separate wages into their natural subdivisions—administrative, distributive and productive—we find the amount expended directly for producing the current to be the dominating one in the matter of the cost of furnishing current to the consumer. Comparing the productive wages, we find that in different sections of the country there is very little variation in the amount paid to the engineer, to the fireman, to the coal-heaver and the auxiliary help in the machine-room, so that, for practical purposes, it would not do to base the price of current on this factor alone. It is necessary, therefore, for us to look farther and seek some factor that shows a decided variation, and, at the same time, is one of the principal factors in the cost of producing current. The factor that seems to fulfill such conditions is coal. A glance over prices paid for coal in different sections of the country shows a very wide variation, and, at the same time, a consideration of the coal itself, as to its quality, shows a variation in evaporative power per pound of coal; which variations ought, strictly speaking, to enter as a factor in determining price, and, in order to get accurate results, should be so used: *i. e.*, placing evaporative power of first quality coal at 12, then the price paid for coal should be multiplied by the ratio between 12 and the evaporative power of the coal used to determine the true value for comparison.

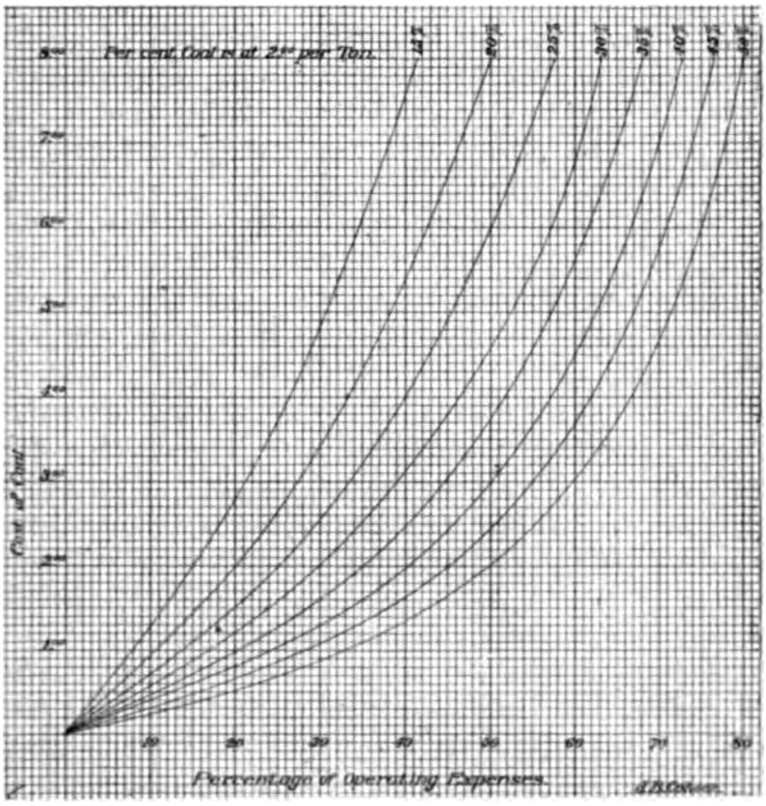
In determining a base price which should be

charged per kilowatt nour, it is necessary to start with some kind of coal at a certain price, and which enters as a certain per cent into the operating expenses. For this purpose, bituminous coal, with evaporative power of 12 and price $2 per ton delivered at the bunkers, has been taken, and it is assumed that with this coal at the price mentioned, it enters as a factor at practically 25 per cent of the total cost of operating expenses of the company, said operating expenses including every expense attendant upon the production and distribution of the current and the administration of the company, also including taxes and insurance, but not expenditures for wiring of buildings or fixed charges. For example :

Assuming cost of operating expenses at $40,000, cost of coal as $10,000 at $2 per ton, we obtain the cost of coal as 25 per cent of the operating expenses. This gives one point of a curve which may be plotted for showing the effect of variations in the price of coal, other expenses remaining the same. Going further and plotting a curve on this basis, if the price of coal is $1 and other expenses remain the same, we then have the total cost of operating expenses as $35,000, of which coal is $5,000, or 14.28 per cent. If coal is $4 per ton, the operating expenses are increased $10,000, and total operating expenses become $50,000, of which coal costs $20,000, or 40 per cent. In a similar manner, using other per cents, other points may be determined and curves drawn through these points, the curves partaking of the form of a parabola passing through the origin ; such curves are shown herewith ; the division of the scale of ordinates being dollars, and of the abscissa per cent.

If, now, we fix on 20 cents per kilowatt hour as the price which the consumer should pay on a basis

of coal of evaporative power 12 and price \$2 per ton, then if the same quality of coal can be obtained for \$1 per ton, the price per kilowatt hour should be multiplied by one minus the per centum corresponding to the price of \$1 per ton, or $20 \times (1 - .1428) = 17.144$; and if the price of coal be doubled, or \$4 per ton,




the price per kilowatt hour should be $20 \times (1 + .40) = 28$; the rule being to make the price, where fractions are obtained, the nearest whole number: thus, coal at \$1 gives 17 cents per kilowatt hour. Similarly, the price that we should charge for arc lighting and power should be referred to the same standard. It should

be clearly understood that the above assumption of coal at $2 per ton, and entering as 25 per cent of the total operating expenses, is only made for the purpose of obtaining a starting point to present this idea to the members of the convention. In order to work on a satisfactory curve, and one that will fit the conditions of individual stations, each must figure out what per cent of their operating expenses coal would be if they had to pay $2 per ton for standard coal, and start with this per centum as a basis on which to determine the proper curve for their own particular case.

Suppose each station were to make such a curve, and from it work out for itself the price which it should charge for current, and compare the price so obtained with the price that it is actually getting. This would then show whether the price should be advanced, in order to show a fair margin of profit. This is offered to the convention as a suggestion for the purpose of bringing the subject up for discussion and for determining whether, in the opinion of the convention, it is advisable to establish such a basis, and, if it is wise to so establish a basis, whether it should recommend its adoption to the members.

Intimately connected with the price that should be charged, is the determination of the cost per kilowatt hour. Each station has certain blanks which they use, largely with the view of enabling the superintendent or manager to determine the output and its cost, and it seems to me that the question of such blanks offers a fruitful theme for discussion. There are numerous blanks used in many stations that are merely for the purpose of keeping track of supplies, etc., and of which it is not necessary to treat, as each station manager has his own ideas on this subject,

and they concern no one but his own company; but the question of blanks for showing output of the station and its cost is one that may well be discussed by the members of the convention, and an effort should be made to secure a standard set of blanks that will show these points in such a clear way that the information may be available for comparison and discussion in the conventions. I present herewith specimen blanks which show the system designed for our station, and among them will be noticed two forms of dynamo tender's report, marked A and B, respectively. The former we used prior to putting recording wattmeters on the alternating circuits, and the other, which we are now using, since the introduction of the wattmeters. The first blank entailed a considerable amount of work, and necessarily gave only an approximate result, but it was better than having no record at all, and, in one sense, the second blank, marked B, gives an approximate result also, as no recording wattmeters are used on the arc circuits. You will note on blank marked A that hourly readings of the alternating-current volt and ammeters are taken from ten o'clock p. m. of one day to three o'clock p. m. the next day, this being during the light-load hours, when the variations are small; during the heavy-load hours, from 3 p. m. to 10 p. m., half-hourly readings are taken. Many of the smaller stations would not feel warranted in going to the expense of purchasing recording wattmeters for their incandescent circuits, and for this class of stations this form of blank is recommended. For the larger stations, which can afford to keep more accurate records, Blank B is recommended. Blank C, the engineer's daily report, is probably the same in substance, if not exactly so in form, as is in use by a majority of the stations at

the present time, and will be found, it is thought, sufficiently complete to give the results sought for without going into too many details.

Blank D is the superintendent's daily report, and is intended for the larger stations having a general

**→A←.**

## The Elmira Illuminating Co. Dynamo Tender's Daily Report.

For the Twenty-Four Hours ending 6:00 o'clock P. M., .......... 189 All circuits tested at 10:00 o'clock A. M., and 1:00 and 4:00 o'clock P. M., and found free from grounds and crosses except as below noted.

| | | | TIME NOTED | TIME REPORTED | TIME CLEARED | CAUSE IF KNOWN |
|---|---|---|---|---|---|---|
| ARC CIRCUITS | No. | Grounded, Crossed or Open. | | | | |
| | No. | " " | | | | |
| | No. | " " | | | | |
| A. C. CIRCUITS | No. | Grounded, Crossed or Open. | | | | |
| | No. | " " | | | | |
| | No. | " " | | | | |

City Arc Lights started yesterday at .......... P. M.
City Arc Lights stopped this morning at .......... A. M.
Total hours run, ..........

Commercial Arc Lights started yesterday at .......... P. M.
Commercial Arc Lights stopped this morning at .......... A. M.
Total hours run, ..........

Approximate Total Number of Arc Lamps in Service ..........

Railway Generator started yesterday at ..........
Railway Generators stopped yesterday at ..........
Total hours run, ..........

Kilo Watt hours registered by Ry Watt Meter for 24 hours, ending 4 P. M., this date. ..........
Kilo Watt hours registered by Power Circuit Watt Meter for 24 hours ending at 4 P. M., this date. ..........

HOURLY READING OF ALT. CURRENT GENERATOR VOLT AND AM. METERS FROM 10 O'CLOCK, P. M. TO 3 O'CLOCK, P. M.

| Machine No. | 10 p. m. | | 11 p. m. | | 12 m. n. | | 1 a. m. | | 2 a. m. | | 3 a. m. | | 4 a. m. | | 5 a. m. | | 6 a. m. | | 7 a. m. | | 8 a. m. | | 9 a. m. | | 10 a. m. | | 11 a. m. | | 12 noon | | 1 p. m. | | 2 p. m. | | 3 p. m. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Totals | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

HALF-HOURLY READING OF AM. METER AND VOLT METERS FROM 3 O'CLOCK P. M. TO 10 P. M.

| Machine No. | 3:30 p. m. | | 4 p. m. | | 4:30 p. m. | | 5 p. m. | | 5:30 p. m. | | 6 p. m. | | 6:30 p. m. | | 7 p. m. | | 7:30 p. m. | | 8 p. m. | | 8:30 p. m. | | 9 p. m. | | 9:30 p. m. | | 10 p. m. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. | Volt | Amp. |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Totals | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Average Number of Volts for 24 hours run .......... Average Number of Amperes for 24 hours run ..........

Remarks ..........

Signed .......... Dynamo Tender.

Note all complaints of service reported by telephone or otherwise.

manager, and is designed to give the latter a general idea of what has been done, what has been used, what material has been received, what is required and for which requisitions in due form will be made out. Blank E is the superintendent's monthly report made

# B

# THE ELMIRA ILLUMINATING COMPANY.

## Dynamo Tender's Daily Report.

**For the Twenty-four Hours ending 6.00 o'clock P. M** .................189 . All circuits tested at 10.00 o'clock A. M., and 1.00 and 4.00 o'clock P. M., **and found free from grounds and crosses except as below noted.**

| | | Time Noted. | Time Reported. | Time Cleared. | Cause if Known. |
|---|---|---|---|---|---|
| Arc Circuits. | No........Grounded, Crossed or Open.... | | | | |
| | No........ " " | | | | |
| | No........ " " | | | | |
| A. C. Circuits. | No........Grounded, Crossed or Open.... | | | | |
| | No........ " " | | | | |
| | No........ " " | | | | |
| Ry. Way Circuits. | No........Grounded or Open.... | | | | |
| | No........ " " | | | | |
| | No........ " " | | | | |
| Motor System. | Grounded, Crossed or Open.... | | | | |

City Arc Lights started yesterday at.......P. M. | Number of City Lights in service..........
" " stopped this morning at.......A. M. | Estimated watt hours output..........
Total hours run ..........

12 M. Arc Lights started yesterday at.......P. M. | Number of 12 M. Lights in service..........
" " stopped this morning at ...... | Estimated watt hours output..........
Total hours run ..........

10.15 P. M. Arc Lights started yesterday at ......P. M. | Number of 10.15 Lights in service..........
" " stopped yesterday at.....P. M. | Estimated watt hours output..........
Total hours run..........

Watt hours registered by Railway Wattmeter for twenty-four hours ending 6.00 P. M., this date ..........
" " Power " " " " " " ..........
" " A. C. " " " " " " Mch. No. 1..........
" " " " " " " " " Mch. No. 2..........
" " " " " " " " " Mch. No. 3..........
" " " " " " " " " Mch. No. 4..........

**Total station output for 24 hours ending 6.00 P. M., this date**.......... Watt hours..........

**Remarks**.....................................................................

Note all complaints of service reported by telephone or otherwise.

Signed........................Dynamo Tender.

to the general manager of large companies, but should be made out by superintendents of small companies also and filed in a book kept for this purpose, so that they may at any time turn to it and get any information that is desired, or make comparisons between the output and cost from month to month. The main feature of this blank is that in a comparatively small space it gives the total cost of operation of the

THE ELMIRA ILLUMINATING CO.

NIGHT / DAY ENGINEER'S REPORT

For the Twelve Hours ending 7 A. M. .................................................. 189..

| Engines in Service | | Time Started | Time Stopped | Hours Run | Boilers in Service | | Days Run | Date when Cleaned | Steam Press in lbs | Waste used in lbs | Pack'g used in lbs | Kind of Packing | Qts Engine Oil used | Qts Cyl Oil used | Lbs Grease used | Qts New Oil used | Filtered Oil used | Lbs of Coal Consumed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 1 | | | | | | | | | | | | | |
| 2 | | | | | 2 | | | | | | | | | | | | | |
| 3 | | | | | 3 | | | | | | | | | | | | | |
| 4 | | | | | 4 | | | | | | | | | | | | | |
| 5 | | | | | 5 | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | |

Remarks: ..................................................

Signed .................................................. Engineer.

station for the month, the total amount of supplies used, the output of the station, the number of new lamps, motors, etc., connected, and also the loss, if any, in either lamps or motors. From the office the manager will have the report of the amount billed out for the current used for incandescent and arc lamps and motors during the month, and, by comparing the two, can readily ascertain whether the business for the

## D

# Superintendent's Daily Report for THE ELMIRA ILLUMINATING COMPANY.

TWENTY-FOUR HOURS ENDING 10 A. M.

| DATE ____ 189 | CURRENT DELIVERED TO SWITCHBOARD. | | | | COAL. | | | OIL. | | | WASTE. | | | WATER. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIND | Arc. | Inc. | Power. | Railway. | Used. | Received. | Required. | Used. | Received. | Required. | Used. | Received. | Required. | Used. |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

## GENERAL SUPPLIES.

| | CARBONS. | | | DYNAMO AND STATION SUNDRIES. | | | LINE SUNDRIES. | | | INCANDESCENT LAMPS. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIND | Used. | Received. | Required. | Used. | Received. | Required. | Used. | Received. | Required. | Renewed. | Received. | Required. | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

Remarks:

Superintendent.

# E

# THE ELMIRA ILLUMINATING COMPANY.

SUPERINTENDENT'S MONTHLY REPORT. MONTH OF ............ 189 .

| Received | | | | Consumed | |
|---|---|---|---|---|---|
| ARTICLE | Amount | Cost | | Amount | Cost |
| Coal | | | | | |
| Waste | | | | | |
| Water | | | | | |
| Arc Globes | | | | | |
| Dyn. Sund. | | | | | |
| Engine Sund | | | | | |
| Station Sund. | | | | | |
| Cylinder Oil | | | | | |
| Engine Oil | | | | | |
| Grease | | | | | |
| | | | | | |
| CARBONS. | | | | | |
| 7-16x12 C. C. | | | | | |
| 7-16x12 Pl. | | | | | |
| 7-16x7 C. C. | | | | | |
| 7-16x7 Pl. | | | | | |
| 5-8x12 C. C. | | | | | |
| 5-8x12 Pl. | | | | | |
| | | | | | |
| LAMP RENEWALS. | | | | | |
| 10 C. P. | | | | | |
| 16 C. P. | | | | | |
| 25 C. P. | | | | | |
| 32 C. P. | | | | | |
| 75 C. P. | | | | | |
| 100 C. P. | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| Total | | | Total | | |

Productive Wages

Distributive Wages

Wiring Wages

Total Supplies and Wages

| Station output in Kilowatt Hours | |
|---|---|
| | Arc ............ |
| | Power ............ |
| | Railway ............ |
| | Alt ............ |

Total Kilowatt Hours

New Incd. Lps. Connected ............ New Arc Lps. Connected ............

New Motors in H.-P. ............ New Fan Motors ............

Incd. Lamps Discontinued ............ Arc Lamps Discontinued ............

H. P. of Motors Discontinued ............ Fan Motors Discontinued ............

Net {Gain / Loss} Incd. Lamps ............ Net {Gain / Loss} Arc Lamps ............

Net {Gain / Loss} H.-P. in Motors ............ Net {Gain / Loss} In Fan Motors ............

Correct.

............................................ Supt.

month, as a whole, has been conducted on a profitable basis or at a loss; whether there has been an increase in the business; whether too much has been expended in one direction and not enough in another, and, in fact, can, in a brief space of time, analyze the entire business for the month in such a way as to give him the information that he needs, in order that he may intelligently conduct the business to a successful issue.

MR. CAHOON: I would say in addition, with regard to that superintendent's monthly report, that it is a sort of cosmopolitan thing, which I obtained from working over the reports of about sixty different stations. Each man has his own particular ideas on the subject, and the only object in putting these in is to bring this subject up, and see if we can not get a standard set of blanks for the particular data that we want to discuss in convention. Gentlemen, I thank you.

## DISCUSSION

THE PRESIDENT: Gentlemen, the paper presented by Mr. Cahoon is now open for discussion by the members. Mr. Beggs, you have had, to my knowledge, a great deal of experience in the preparation of central station blanks and the conservative direction of institutions of this kind; I should like to hear from you with reference to the matter.

MR. BEGGS: I understand that the matter of uniform blanks is to be discussed later in the meeting; probably when we come to the discussion of the question of rates for current, it will come up naturally in that same relation, so I would rather defer what I have to say on the subject until then. I would say, in a general way, however, that I thoroughly concur in the desirability of having uniform

blanks prepared, by which different stations, of the same general character and under the same conditions, might be enabled to compare the results they were realizing. I think I have taken occasion once before in this association—possibly several times—to say that much of the data obtainable in these associations is absolutely worthless for the purposes of the great majority of stations over the country. It is not at all applicable to their conditions. We hear very much of the results obtained in the very large stations, and many station managers naturally become discouraged, and their stockholders disheartened, because they cannot attain to the degree of perfection of economy that seems to be realized in the large stations, when, possibly, under the conditions with which they are contending, there is better evidence of management apparent in the small stations than there is in the large ones about which we hear so much in the electrical journals. It has been my duty in the last twelve, thirteen or fourteen years that I have been in this business, to be interested in some of the largest, and in quite a number of the very smallest, stations; and the people running the large stations have no conception of the difficulties with which the managers of these small stations have to contend, and how much more difficult it is for them to show results. I think that when this matter was before the association twelve months ago, and discussion was had regarding the information that the Committee on Data obtained, I took the ground then that much of the information as obtained was absolutely valueless, because you could not tell by the numbers where the location was, nor what were the conditions under which they were laboring. For instance, I have what might possibly be called the

honor—certainly a very *onerous* duty at the present time—of managing what is a comparatively large station. You would possibly think—and that is somewhat different from what my stockholders think—that it was very uneconomical management if I should tell you that with the best coal produced in this country for producing steam—and I refer to Pocohontas coal, run of mine and selected at that—of the gross receipts of that company in the year 1896, twenty-five per cent went to pay our coal bill. Yet there are some people that do think I am a pretty fairly economical manager. Now, if I were to give that datum—let it go forth in this committee's report that was presented here this morning—much of the record that I have made in the last twelve or thirteen years would, I presume, be dissipated; and yet I know, and those that are conversant with the conditions know, that there is no station in this country—and I say it advisedly—managed under the conditions with greater economy than that is. But with wasteful apparatus, with conditions under which we have been trying to hold a company together until such time as it might be demonstrated either that it had the capacity to earn a return upon a fair amount of capital invested, if invested properly in a proper station, or else demonstrated that it could not be done—we have had all those things to contend with. It has, however, now been demonstrated, gentlemen, that even under those conditions, paying twenty-five per cent of our gross receipts for coal, and that of the best quality, we last year made such a return in that station that the stockholders are now willing to put up between $500,000 and $600,000 to build a modern station in that city, with which to show a comparison. I say it with no disparagement of other engineering

concerns or engineers, but our estimate is that with the new station, the plans for which are under consideration at the present time, with what cost $54,000 for fuel last year, that same measure of business we expect to produce, kilowatt for kilowatt, for $18,000; simply by the difference in the character of plant that is to be constructed, and the different character of apparatus that shall be used in the station. Therefore, Mr. President, in the preparation of any system of blanks, it is very important that these differences in condition should be made to appear, not only that the price of coal and the quality of it should be taken into consideration, but the type of the apparatus that is being used. I believe I had part in the preparation of the first blanks that were prepared in this country by which any uniform system was attempted to be obtained, and which I believe were largely prepared by a gentleman who is on the floor of this convention. I refer to Mr. J. H. Vail, who was the first superintendent and engineer of the old Edison Electric Light Company—the parent company; now the manager at Philadelphia. I believe that he and I labored over a set of blanks some twelve years ago, week after week, trying to get them made uniform. Many of the ideas then suggested have been followed upon, modified in various ways. This is a question, therefore, that requires a great deal of consideration, and it seems to me that it is one which would be well worthy of a special committee of this association. I might say here, without divulging any confidences, that some of the larger stations in the country, and particularly those supplying current from the Edison three-wire system, have agreed upon and adopted uniform sets of blanks whereby the distribution of the various items of expense in the oper-

ation of stations are made exactly the same, and they exchange these blanks, or have them criticized, from month to month. They all see what their different stations are doing, and there is nothing in the world better calculated to bring about an improved condition of station operation than some such plan as that, affording some blank of uniform plan under the same conditions.

MR. COGGSHALL: Mr. President, I recognize the great importance of standard blanks. As the matter will come up later, I now move a vote of thanks be tendered Mr. Cahoon for this valuable and interesting paper.

THE PRESIDENT: It is moved that a vote of thanks be presented Mr. Cahoon for his interesting and valuable paper, and that it be recorded on the minutes of the convention. Is it your pleasure that the motion be carried? And it is added that the discussion be continued later, after the other papers have been read.

Carried.

# THEFT OF CURRENT, AND HOW TO DEAL WITH IT

THE PRESIDENT: The next item on the programme s the topic for discussion, entitled "Theft of Current, and How To Deal With It."

During the past year, when I have been looking into several matters and considering lines or directions in which work could be done that would serve the best interests of the members of the association, I was very much astonished to find that in hardly any state of the Union was there provision made in law for the punishment of any person that would deliberately steal current from the street mains or otherwise. It seems to me that that is something which should be provided for. I know that in Canada we have provision made for the theft of current, and it seems to me that a question of this kind should be taken up by the association, and that the different members should work together, so that there could be a clause added to the criminal code of the different states providing for the punishment of this offense. Mr. T. C. Martin was speaking to me in reference to this matter this morning, and had with him the draft of a law that has just been passed in one of the states. Is Mr. Martin present? I have much pleasure, Mr. Martin, in requesting you to mention to the meeting the points of which you were speaking to me this morning, in reference to the theft of current.

MR. MARTIN: Mr. President, I mentioned to you this morning that I believed I had copies with me of

the bill which has just been passed by the State of Connecticut penalizing the theft of current. I thought I had copies with me, but, on searching my valise, I do not find them. I can say, however, that the bill was brought up at the last session of the Connecticut Legislature, and was referred to a committee, was approved, and returned to the lower house and passed, was sent up to the senate and was passed there; went through both houses, I understand, with very little opposition from any quarter, and, within the last ten days, I think, the bill has received the assent of the governor, and is, I presume, now part of the law of the State of Connecticut. I received the copies of the bill so late that, though I thought I slipped them into my valise, I do not find them. I published the original draft of the bill, however, in the paper that I am connected with, some two or three weeks ago, and, as I remember it, there was a small money fine attached to the offense, or a short term of imprisonment—quite short. The bill seemed to me, at that time, weak in regard to the requirements as to proof of theft. Whether that feature has been improved in the bill as made law, I am not able to say.

I had some conversation not long ago with my friend, I think known to most of you, Mr. Russell B. Harrison, who had encountered the difficulty of theft of current at Terre Haute, and I found that, although the cases (there were more cases than one) were pretty well proven, he had hesitated to bring action, because he was advised by his lawyers that, under the existing state of the law, it would be very difficult to bring home the offense, and if it were brought home it would be difficult to secure a conviction within the law as it then stood. There have, however, I believe, been one or two convictions, and, at any rate—in

Louisville, Ky., I think it was—a saloon-keeper having stolen current recently to supply a fixture in front of his saloon, having tapped onto the adjacent mains, the case coming before the court, his counsel moved for a dismissal of the case, on the ground that it was not in any wise a statutory offense. The judge dismissed that as absurd, and held the offender for trial. Whether the case has since come up or not, I am not able to say. I believe that is all I have to report.

MR. AYER: Mr. President, I think the time is opportune for the association to take action in this direction. We have some little legal talent connected with the association, and I would suggest that a committee be appointed, with a view of composing that committee of lawyers, for the purpose of drafting suitable legislation, or for outlining the points to be covered, for statutes in the different states, and that the secretary supply members with copies of the result of their work. I think we can venture to draw on the good nature of friend Armstrong and some others in this direction, very much to the profit of the association, and I offer this as a resolution.

THE PRESIDENT: Your object, then, as I understand it, Mr. Ayer, is that a bill be drafted by the association, which would meet the requirements of the offense, and that it be uniform, if so passed in the different states, instead of having one law in one state and another in another state, and so on?

MR. AYER: To be something drafted by people who are familiar with the law in this respect, with its weakness, with the elements that have entered in to defeat the prosecutions heretofore. I would have that offered as a standard, and interested members in the different states can endeavor to have it enacted into law by their legislatures; and, if it is uniform through-

out the United States, incorporated into a bill wherein the essential points are conspicuous and not changed, we shall then have legislation in one state which would be quoted and which would be valuable, of course, in other states in confirming and assisting in securing such a law—make it simpler to prosecute, and all that. It would be an easy way to get simultaneous action throughout the country.

Mr. Young: Mr. President, in relation to the law that has just now been passed in Connecticut, it happened to be a duty of my own, as treasurer of the Connecticut Electric Lighting Association, to have this particular bill drafted, and it was drafted by the attorney for our association, and it passed, as Mr. Martin has stated, without any serious opposition through the legislature of our state, and has been signed by the governor. The penalty attached is a fine of fifty dollars or imprisonment for thirty days, or both. We found it very necessary to have a law of that kind passed in our state, and we took active measures and successful measures to have it done.

Mr. Stetson: If it is thought well to appoint this committee, I might say that it would be well to examine the law that is in force in Massachusetts. Last year, or the year before, the law was made to apply to the theft of current the same as to the theft of gas; and it gives me pleasure to report that a man that had ordered out his meter, and had put in wire to occupy the space that the meter previously occupied, and had gone right on with the lighting business,—I put the matter into the hands of the circuit court of our city, the judge heard the case, and it cost the man fifty-five dollars to get about fifty cents' worth of electricity. A singular thing about this case was that the man that drew the law

was the counsel of the man that stole the electricity; and he came up with some very learned legal points, arguing that the whole indictment ought to be quashed, and something that I didn't know anything about. But our judge sat down very squarely on all that, and landed the man just where we wanted him to be, and the moral effect on our community has been very good. I should advise a study of that law. I see that Mr. Barker, of our commission, is here. Perhaps he could give a better idea of the details of the wording of the law than I should be able to do, although it has been very satisfactory in its working in my case.

MR. BARKER: Mr. President, I do not think I can add anything to what Mr. Stetson has said. The law was promoted, I think, by the efforts of the Massachusetts Electric Lighting Association. It was passed by the legislature with practically no opposition, and perhaps the passage of the law was aided by the fact that a law prohibiting such theft of gas had been upon the statute books for a number of years. I think the courts in our state have held that it is not a common-law offense to purloin gas, and, therefore, they would be likely to hold in the same way in respect to electric current; but the statute seems to be a sound one. I think there have been a number of prosecutions successfully carried out under it in our state—if I mistake not, in the city of Lynn. It has been in existence for a couple of years, and is modeled after the law prohibiting and punishing the theft of gas; and I think the general opinion is that it is a good law.

MR. MARTIN: Mr. President, Mr. Stetson's suggestion moves me to believe that perhaps it would be a good thing if I could supply the omission of bringing the bill with me by placing it in the hands

of the official stenographer. That would make it a part of the transactions, and in that way it would very quickly reach a great many members of the association who are not here, and other electric lighting men throughout the country who are very much interested in this question, as I know from the number of letters that I have received on the subject,—and I can do that immediately after the rising of the convention.

THE PRESIDENT: We shall be very pleased to have the draft of the bill, Mr. Martin.

MR. MARTIN: Cases of theft seem to be getting daily more numerous, and now that we are threatened with the application of it, in large quantities, for the purpose of burglarizing safes, it seems to me that it would be well, perhaps, to protect ourselves before that new industry gets upon its feet.

MR. W. P. ENGEL (of Charlotte, Michigan): Mr. President, with your permission and that of the members, as I am not a member of this association, I would say that legislation has been inaugurated in the State of Michigan upon this subject, through the efforts of several central station men, and the Municipal Light and Power Company, of Grand Rapids, sent out a circular which embodies a law called "House Bill No. 955, Legislative Session of 1897." That law embodies punishments, and it also includes gas, water and electric current. I have a copy of it, and if a committee is appointed I will deliver this to them, that they may look at it; or it may be read, if you so choose.

THE PRESIDENT: We shall be very pleased to have you hand it to the secretary.

MR. BEGGS: There are many important considerations in connection with this subject. I have been instrumental in having one conviction brought about

in the city of Cincinnati, although the Ohio law is somewhat indefinite upon the point. We could only proceed under the law that was passed for tapping wires for an entirely different purpose. But this case was so clear that we brought the action. I believe that was the only statute in the State of Ohio. Our counsel is quite an eminent lawyer—ex-Governor Foraker, now Senator Foraker—but we had great difficulty. But our principal difficulty is in tampering with the measuring instruments themselves; not so much tapping the wires,—taking the current direct, as Brother Stetson suggested—but tampering with the measuring instruments. Therefore, when a bill is drawn, it seems to me that it should be broad enough to cover every condition under which a man attempts, not only to steal current, but in any way to tamper with the instruments employed for measuring, which is the most prolific source of loss to the central station. In the case I referred to, we prosecuted the man, and I believe he was subjected to a fine of fifty dollars. But our greatest difficulty was to have the grand jury even bring a bill against him, because of his political pull. He was a prominent saloon-keeper, and if we had not had, through our counsel, a stronger political pull even than he had, we could not have convicted him at all. It required very peremptory orders, sent four or five times to the district attorney, to have that case presented to the grand jury, and I think it stayed there for several months. But it was a saloon in which we had never even furnished the current; he had been cut off by one of our competitors for non-payment of bill. Our lines happened to cross near the rear end of his premises; he threw out a grappling hook and got connection on there, and lighted himself for several months in that way. There

was really no law in the State of Ohio except we prosecuted him upon the charge of tapping wires under a law that was passed for the protection of race courses and things of that kind. There is nothing for electric lighting companies.

MR. CLAY: I believe, Mr. President, the motion is to refer this matter to a committee. I fail to see how any such committee could accomplish any results satisfactory to the members of this association, owing to the fact that the conditions differ in the various states of the Union. The fact has been made known here, however, that, in a number of states, there is a statutory law making it a criminal offense to steal current, or to interfere in any way with electrical devices or apparatus. The president states that they have such a law in the part of Canada whence he comes. Two years ago we put upon the statutes of Pennsylvania a law that makes it a misdemeanor, punishable on conviction by fine and imprisonment, for any person to take current, or in any way to interfere with electrical apparatus. Now the thought has occurred to me that we could best accomplish the end we have in view if the secretary would request the delegates here from the states that have satisfactory laws upon this subject to send copies thereof to him, and have all these various statutes printed in the proceedings of this convention, as an appendix or addenda for reference and for information. In that way, the members of any state having no such law, if they desired to make an effort to have one enacted, could have what has already been done in other states as a guide. I believe that in that way you could accomplish better results than you could possibly bring about by referring the matter to a committee.

MR. AYER: In suggesting a committee, I had

in mind that it was wise to put this into the hands of men who were informed as to the electrical requirements as well as the legal points. It seemed to me that it went without saying that any lawyer who would be a member of that committee would naturally gather together all such data of this nature as were available, and out of the whole evolve a law that would be much better than would be likely to be evolved by lawyers or counsel of electric companies to whom interested members of the association might submit even the grouping of a lot of laws. The very point that is raised by Mr. Beggs—that it is desirable to cover not only the stealing of the current, but the tampering with the measuring instruments—is a thing that should be embodied. The points that we are raising here in this discussion are all being absorbed by Judge Armstrong, and from these various explanations he will be enabled to compile an outline for a law that will cover the points. This seems to me much better, and a method that will accomplish our object much more quickly throughout the country than anything that could be accomplished in the other way.

MR. BEGGS: I agree with Mr. Ayer's suggestion as to the desirability of having a committee appointed. They would naturally get before them all the legal enactments bearing upon this subject, and, knowing from practical experience what the conditions are and the sources of stealing, they could at least give us an outline of a law that might be suggested to the various states through the various state organizations, with whom I think the secretary of this association should be in very close communication; and with these various state organizations giving them the drafts of their several bills, I should think that a bill

might be presented that would cover these various practical points. These matters are too often taken up without the knowledge that Mr. Ayer has suggested, and we get a bill passed that doesn't cover the ground at all. I should, therefore, very much like to see a committee of this association appointed to draft the outline of a law that might be followed pretty uniformly throughout the United States.

JUDGE ARMSTRONG: From what has been said in relation to the various laws that have been passed, I judge that the penalty is grossly inadequate. You know there is an old adage, that where there are twelve lawyers there are always thirteen opinions. But I am strongly under the impression that if a grand jury should return a bill of indictment for larceny to my court against a man for tapping a wire and taking power, and the jury believed that he had done it, I should not hesitate to sentence him for larceny under the law as it now stands. There is nothing in our state that I recall —no decision of the Supreme Court—that would prevent that thing. This proposed bill in Michigan and the one in Connecticut make it a slight misdemeanor only. If a man steals above thirty dollars, I think it is, it is grand larceny, and he may be imprisoned for from two to five years, depending on the circumstances. Here, in this bill, three months and one hundred dollars, is the maximum penalty. In the Connecticut bill it was fifty dollars. The difficulty about our taking it up would be in the way of recognizing that the courts have declined to hold it as a crime. It would be our representative body admitting that the power communicated by the wires and the cables was such an intangible thing as to have no property in it, if you take this action. That is what the courts have held. They have said: "Well, we do

not know what electricity is; nobody else knows what it is, and therefore it isn't anything, and nobody can have any property in it. It is as free as air, and as independent of ownership as light or water; and, that being the case, no one can steal it; that being the case, the diversion of it cannot be a crime." If we are to do anything in the line of legislation, I think it ought to be this: To pass bills to prevent frauds upon lighting, water and power companies, say, and let it apply to any person who, by any device or contrivance, seeks to deprive them of their revenue or interfere with their apparatus, and so on; not by any act of ours recognizing that up to this time it has been no violation of the common law to take current, to take power; up to this time it has been no offense, and is only an offense now because the legislature has, in its wisdom, said so. I am not willing to admit that; I do not think that any of us ought to be willing to admit that. But we can with propriety, if it is thought advisable, recommend legislation to prevent frauds against these companies, the same as they have to prevent frauds against railroad companies in some places, you know, in the sale of tickets by scalpers. I believe, however, the title of those acts is always "to prevent frauds against travelers." I believe that is the way it reads in the title of the acts. So we might have to borrow from that suggestion and make the title of our act read in that way. But what I want to do is to protest as strongly as I can to this association against their recognizing by anything they do the propriety, if I may say so, of anybody's taking electric current the same as they would take in sunlight or air. That has been the idea upon which they have acted heretofore, and we may, by any act that we do, give a good deal

of credit, a good deal of strength, to that. The judges of the courts—those who are administering the law—know nothing about these mechanical contrivances—of course, don't know much about the scientific—they do not have to know about it scientifically; and there is that ignorance existing, which is present in our legislatures, present in every court. And so, if we who are in this business start out admitting that there cannot be a theft of this thing, that there is no law to punish it, and, therefore, we want to have a new law made for it, don't you see how far we are going? If we were supplying any other product, it would be fully understood, and an indictment under the common law for larceny would thoroughly lie.

THE PRESIDENT: It has been moved and seconded that the chair appoint a committee of three to prepare a report upon this subject, and draft a bill that would be uniform and would apply to all the different states; and the mover of the resolution also suggests that, as soon as that report be drafted, it be forwarded to each of the members of the association. Is it your pleasure that the motion be declared carried?

Carried.

THE PRESIDENT: The convention ordered this morning that the report of the Committee on Standard Electrical Rules, Capt. William Brophy, chairman, should be presented this afternoon. I now call upon Captain Brophy, as chairman of the committee, to present his report.

# REPORT OF COMMITTEE ON STANDARD ELECTRICAL RULES

*Mr. President and Members of the National Electric Light Association:*

At the nineteenth convention of this association, held in New York city, a committee, to be known as the Committee on Standard Electrical Rules, consisting of five members, was appointed, with instructions to select one of its members, or some other person, to represent the National Electric Light Association in the National Conference on Standard Electrical Rules.

This committee was the successor of the one appointed at the fourteenth convention of this association, known as the Committee on Rules for Safe Wiring, and subsequently known as the Committee on Standard Rules for Electrical Construction and Operation, which was discharged on its own recommendation at the same time. This last named committee has labored faithfully since its organization to bring about the much desired end, the establishment of a uniform standard set of electrical rules governing all electrical installations, to be enforced by the five insurance companies and municipal inspection bureaus. This task was no easy one for this committee. Its efforts met with fierce opposition from some, and indifference on the part of others. It received some encouragement from the press at times, and no small opposition at others. Some portions of the insurance

interests looked upon it with favor, but a large portion opposed its aims and purposes. The principal obstacles to be overcome were:

Indifference on the part of those most deeply interested—those engaged in the electrical industries. They somehow believed that the fire underwriters of the country were more powerful than the municipal, state, or even the United States, governments; that any law, edict or rule issued by them, whether right or wrong, could be enforced and must be obeyed. For the benefit of this class, your committee must say that such is not the case. The fire underwriters are the receiving and disbursing agents of nearly the whole of the people of the country, receiving their money as a consideration for indemnity against total loss by fire. The larger proportion of the money they receive is returned as partial compensation for the losses sustained; the balance pays the expenses of the business and a varying amount of profit to the holders of stock and the policy-holders of mutual insurance companies. The greater the care in selecting fire risks, and the more careful the supervision of them while insured, the greater the profit.

The next obstacle to overcome, was the prejudice of the average underwriter against electricity when introduced into the property he insured. To those who witnessed the methods adopted by those who installed the first electric light, and know something of the losses sustained by the insurers and insured, this prejudice is excusable. Up to that time, electricity had proved itself a useful and harmless servant, the only evidence of its ability to produce heat or flame being offered at the contact points of the telegraph relay and key; but when this very small spark was increased at the carbon points to such size and

intensity as to rival in brilliancy the sun's rays, its power for good and evil was wonderfully increased. Those who could keep under perfect control the feeble battery current, did not possess the necessary appliances or knowledge to keep this new form of electrical energy under proper restraint, while the fire underwriters paid heavy tribute to it in the form of burnt offerings and in the shape of indemnity to the policy-holders.

Under such circumstances, who could blame these powerful bodies for taking alarm and looking upon the new candidate for public approval with disfavor? They were between two fires, as it were--those caused by electricity improperly harnessed, and that of enthusiastic admiration kindled in the breasts of their policy-holders for the electric light; they would have it, even if it did increase the fire hazard. How to get out of this dilemma was the burning question. They did not want to abandon a formerly profitable part of their business, but feared they must. Two remedies were tried: First, increased insurance rates was the penalty exacted for the introduction of electric lights. This plan proved ineffectual, because it did not prevent losses in excess of premium rates, and it opened up a new field for the illegitimate underwriter, who preys on the insurer and insured alike in the end. The second remedy proved more effective. They called to their aid some of those who were supposed to know how to lead this new and unknown force along the straight and narrow path designed for it, and not permit it to wander into their domain and change fat dividends to heavy assessments. Such men were scarce, and most, if not all, of those engaged were obliged to learn by experience the best methods of procedure; the same

can be said of those engaged in the electrical business. The acquisition of such experience, up to a few years ago, proved very costly to the fire underwriters and others as well.

Gradually, fire insurance associations appointed one or more inspectors to examine the electric light wires, lamps and fixtures installed in their territory, and to enforce certain rules and requirements, generally made by themselves. With the rapid advance of the electrical industries, changes in these were inevitable, but lack of uniformity proved to be a crying evil. The best and most reasonable requirements were formulated in those sections of the country where the electric light had found a foothold earliest. Most of the inspectors, instead of profiting by the experience of those longest in the business, and adopting the rules formulated by them, insisted on issuing productions of their own, so that the so-called insurance rules differed as widely as the excise laws of Maine and New York. Some sections of the country were fortunate enough to have men who were empowered to make rules and enforce them; whose elevation to such position did not make them dizzy, and cause them to issue impractical requirements, the enforcement of which did not always serve any good purpose, but made life a burden to those who were so unfortunate as to come under their jurisdiction, whether manufacturers, contractors or producers of electrical energy. But other sections were not so fortunate. Among all the burdens that those in the electrical business have had to bear in the past, the whims and caprices of the authors of insurance rules have not been the least.

The loss of time and money, caused by conflicting requirements, became so great in time that a movement was inaugurated by this association for securing uni-

formity of rules—a codification of the best, and repeal of the productions of cranks and impracticals. This task was accomplished by your former committee, the result of their labors approved, and the first national code issued by this association. It was also adopted by the insurance associations, who thus recognized the good work performed. After the issue of this national code, it was thought that all the troubles here described were ended. Such, however, was not the case, for while the best representative men of the fire insurance associations agreed that the electrical engineers or electric light superintendents were the proper ones to formulate rules and requirements, and the insurance associations should enforce them, there were others holding subordinate positions who could not bear to have this sentiment put in practice. As a result of such feeling, an organization arose, known as The Underwriters' National Electric Association, which has claimed the sole right to issue new or amend the original rules first issued by this association, and has, in the past, insisted that the electric and allied interests should have no voice therein. As time rolled by, and the organization increased in numbers, this sentiment changed somewhat, due to the influence of broad-minded, practical men, who are members of it, and to the efforts of your former and present committees, and last, but not least, to those of the National Conference on Electrical Rules, which was organized through the untiring efforts of the chairman of the Committee on Standard Rules for Electrical Construction and Operation and his associates.

As a result of our combined efforts, the last codification of, and amendments to, the national code is the result of the combined efforts of the National Conference on Standard Electrical Rules and the Underwriters' National Electric Association.

The right to do this is what your committees have contended for in the past, and have finally obtained. Your present Committee on Standard Electrical Rules selected its chairman to represent you in the National Conference on Standard Electrical Rules, which was organized at a meeting held in the city of New York, on March 18th and 19th, 1896, consisting of representatives of insurance, electrical and kindred interests, from the following organizations: National Electric Light Association, American Institute of Electrical Engineers, American Street Railway Association, National Board of Fire Underwriters, American Institute of Architects, International Association of Fire Engineers, Underwriters' National Electric Association, Factory Mutual Insurance Association, American Society of Mechanical Engineers, Western Union Telegraph Company, Postal Telegraph Company, American Bell Telephone Company, General Electric Company and Westinghouse Electric and Manufacturing Company. The complete list of official delegates and organizations to whom invitations were extended, can be found in the report of the committee presented at the last convention, and published in the last volume of the proceedings of this association.

That body appointed a committee on code, consisting of seven members, one of whom was your representative. To this committee was assigned the task of amending and codifying Standard Electrical Rules. At the time of the last meeting of the National Conference upon Standard Electrical Rules, a large amount of work was done by representatives of the various electrical, insurance, architectural and allied interests, tending toward the adoption of the one single standard code of rules. A pamphlet had been prepared embracing the various codes used most extensively in

this country and abroad, and, after these had been in substance considered, and many changes, omissions and additions suggested, it was deemed desirable that the results of the two days' careful discussion should be handed over to a special committee of seven, with the president a member *ex-officio*, which committee should draft a code based upon the lines suggested, and then refer the same back to the conference for its approval.

Since the meeting of the conference, the committee has, by meetings and correspondence, carefully taken up the work assigned to it. The most important meetings were held October 16th and 17th, 1896, and December 11th and 12th, 1896. Between these two dates, *i. e.*, on December 8th and 9th, the annual meeting of the Underwriters' National Electric Association was held, and at the October meeting of the Code Committee, it was decided that the committee, through one of its members (Mr. Merrill), should submit the draft already prepared by them to the Underwriters' National Electric Association, to secure the benefit of their criticism and suggestions, and with a view of insuring a hearty co-operation on their part. It was so arranged that a joint meeting should be held, of our Committee of the Code and a committee from their association, to facilitate the preparation of the final draft of the code. This meeting, held in December, 1896, was very successful, and it was jointly agreed by the two committees: (1) That the title of the new set of rules was to be "The National Electrical Code;" (2) that the National Board of Fire Underwriters, in printing the code, should give on the inside of the cover due credit to the National Conference for its work, and place upon the cover the names of all the associations forming the National Conference, as fast as these bodies gave their indorsement of the code ;

(3) that, as far as possible, the code should be left in the form as then presented, save that the classification as recommended be tentatively adopted, and, after being set up by the printer, be resubmitted in dummy form for final consideration by the members of both committees.

The members of the Code Committee of the National Conference, having met in New York, May 19th, 1897, passed the following resolutions:

*Resolved,* That each delegate who attended the National Conference on Standard Electrical Rules be sent a copy of the Standard Electrical Code, stating that said code had met with the approval of the Code Committee of the National Conference and the Code Committee of the Underwriters' National Electric Association, and stating the belief of our committee that there was no necessity for calling the conference together again as a body, entailing, as it would, a very considerable sacrifice of time and money, and requesting their immediate reply if they acquiesce in this recommendation and approve of the report submitted by the committee and by the president, secretary and treasurer of the conference itself. In the event of their objecting, and desiring that the conference be called together as a body to receive the committee's report, answer is to be made within ten days, or their opinion is to be considered as favorable, and the code reports published through the press by the Code Committee, and each delegate represented at the conference requested to bring same formally before his association for approval.

A meeting of the committee was held in Boston on the 5th instant, at which its previous action was ratified, and the code, as a whole, unanimously adopted.

The National Electric Light Association was the first to adopt and issue a national standard code of rules, and if it now adopts the new codification of them, it will be indorsing, not only the unanimous findings of its committee, but the unanimous action of the Code Committee of the National Conference on Electrical Rules, which conference was organized under the auspices of the association; and, furthermore, it will be the first body represented in the National Conference to do so, and your committee earnestly recommends that you give your approval.

Respectfully submitted,

WM. BROPHY, Chairman.

DISCUSSION

CAPTAIN BROPHY: Mr. President, I believe I was one of the original members of the first conference, held at Cape May, to bring about this result. I have been a member of this committee from that time until now. I have labored faithfully to bring about this end. Sometimes, as I have described here, the task seemed almost hopeless, but I never was ready to yield the right of the men engaged in the electrical business to have their say in the formation of rules under which they were obliged to install their apparatus. As I said before, I have given both time and means to bring about this end. I hope to see it consummated; then I shall be satisfied, and shall consider my work done.

MR. AYER: As a member of this committee, I have been associated with Captain Brophy for a number of years, and there is no one that knows bet-

ter than I the immense amount of labor that he has devoted to this work. I realize, as all the members of the association do, the attitude of the insurance interests, the adoption of rules by those interests, their refusal to recognize the rules of this association, and our repeated efforts to bring about some sort of harmony, and feel now that we have not only done that, but that we have associated with us in indorsing the National Code of Rules the American Institute of Electrical Engineers, a body that has heretofore refused to consider this question, for the reason that they preferred to keep out of all commercial matters and keep the Institute free from any association with commercial factors whatever, as is the case in almost all institutions of a similar character. But they have realized the importance of the subject, and have given their influence to bring about this common result, because they felt that it was necessary for the development of practical electrical work on proper lines that every effort, every power, every influence, should be brought to bear to bring about a universally standard code, and to avoid the unlimited amount of friction which had developed in the past. In addition to that, there is the National Board of Fire Underwriters, the American Institute of Architects, the International Association of Fire Underwriters, the Underwriters' National Electric Association, the Factory Mutual—covering all of the important insurance interests—the American Street Railway Association, of course, as well,—when all that has been accomplished is taken into consideration, we realize the value of the work done. And I want to say right here—and I cannot say it too strongly, I want to repeat it—that Captain Brophy is the man that has done it. We have all done a little pushing and a

little helping, but he has been the leader; it has been his baby from the beginning, until now he has got a well developed child. The rules are long. They are better than those we adopted at our last revision of the rules. They are not just what we want in every particular,--I do not think we shall ever get them so--but I think we can take no chances in unanimously adopting the recommendation of the chairman of this committee, to be the first to indorse the national code.

MR. SEELY: Mr. President, I should like to ask Captain Brophy whether the municipalities have not adopted these rules. In the city of New York, the fire department has an inspector of wiring, and I think he is present here; I should like to hear from him—Mr. Henderson.

THE PRESIDENT: We should be glad to hear from Mr. Henderson, if he is present.

MR. CARNES: Mr. President, I should like to move the adoption of the report.

CAPTAIN BROPHY: I should like to answer Mr. Seely, that among other things I have tried to do in bringing this about is to inaugurate an association of municipal inspectors, so that they would act with every one else and have the thing harmonious. That will be consummated within a very short time.

THE PRESIDENT: It has been moved and seconded that the report of the Committee on Standard Electrical Rules be received, and the suggestions therein adopted. I might say that this is one of the things that, through the energy of our chairman of this committee, has been brought to a successful conclusion this year. It has not been the work of a year, however. From the very commencement, as stated by Captain Brophy, this work has been carried on by

him and by other energetic members of our association, from time to time, under the greatest possible difficulties. At first, the fire insurance parties would not receive any suggestions at all from the electric companies. They made their own rules, and they were, like the laws of the Medes and Persians, unalterable. But to-day we see that this association, through the chairman of its committee, has been successful, not only in having the rules adopted that were first promulgated by this association, but that all the other leading bodies of the country that are interested in such matters were willing to meet in a general conference to discuss these rules, and I think that it is with a great deal of gratification that we may assure ourselves that, if this resolution is passed to-day, we shall be the first to indorse the codification of the rules as agreed upon by all these various bodies, as we were the first to start the agitation. Is it your pleasure that the National Electric Light Association be the first to indorse this codification.

Mr. Carnes: I should like to ask Captain Brophy —for information—if the adoption of these rules by the National Board of Underwriters does not commit and hold them, or does that license them to make additions hereafter, as they may see fit, for their inspectors, without the consent of this association? They have no such right, have they?

Captain Brophy: No, sir; they have now conceded the right of others.

Mr. Carnes: Why I ask the question,—we are very much annoyed in Tennessee by these little slips of paper issued by some unrecognized authority; and the more ignorant the inspector with whom you have to deal, the more annoying become these little unauthorized slips, until it requires more patience than

most of us have to submit to it. I am now rather at war with the Board of Underwriters because I declined to recognize them.

CAPTAIN BROPHY: I will say that hereafter you can return the slips, and hold up this code as the one that you are called on to work under, and nothing else.

THE PRESIDENT: Gentlemen, are you ready for the question?

MR. BEAN: Mr. President, I would suggest that you ask for a rising vote on that resolution.

THE PRESIDENT: At the suggestion of Mr. W. Worth Bean, I would ask all in favor of adopting the resolution to indicate it by rising to their feet.

THE PRESIDENT: I declare the motion carried unanimously. (Applause.)

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THE PRESIDENT: The next order on the programme is a paper on municipal lighting, by Mr. W. Worth Bean, of St. Joseph, Michigan. I will call upon Mr. Bean to read his paper.

# MUNICIPAL LIGHTING

*To the President and Members of the National Electric Light Association :*

The subject to which I would respectfully invite your attention is one of the most vital questions, and of the most momentous importance—not only to the profession to which we have the honor to belong, but also to various commonwealths of which it is our pride to be citizens—that has ever arisen in this advanced electrical era. Municipal ownership of electric lighting plants, the most discussed of all the questions of municipal polity, is the more insidious that it comes dressed in the sheep's woolly garb of a philanthropist, which to the uninitiated and ignorant has an alluring and plausible aspect, but to the experienced are plainly visible the wolf's deadly fangs, which have, in every instance, sooner or later lacerated the taxpayer. The authors and promoters of this alluring scheme are either visionary theorists, who have no practical knowledge of its manipulation, or unscrupulous politicians who, desiring to pose as benefactors to the municipality, hope to ingratiate themselves in the hearts of the voter and thus secure political plums for themselves and their henchmen. That there are many honest supporters of this political fad who, having been deceived by beautiful but false reports from cities which are experimenting with this question, are misled by political demagogues, is undeniable.

The tidal wave is sweeping over our land, and

certain municipalities are now on the crest, but it will not need the average period of depreciation in a plant for the wave to subside and leave the wrecks stranded with increased burdens and depleted treasuries. Already cities have sold their plants, paying dearly for their experience, and others are looking for buyers, in order to unload their "white elephants". Municipal ownership is contrary to the spirit of republican institutions.

From the Declaration of Independence we read: "We hold these truths to be self-evident; that all men are created equal; that they are endowed by their Creator with certain unalienable rights; that among these are life, liberty and the pursuit of happiness; that to secure these rights governments are instituted among men." These are the fundamental principles of our republican form of government, and nothing therein can be construed to mean that government was instituted for the purpose of becoming a commercial producer. The framers of our Constitution had no idea that the government that they were establishing would ever enter the field of competition to the discouragement of private enterprise. The political demagogue of the present day would read the above extract about as follows: That all men are created equal—except central station men; they are endowed with certain unalienable rights—except central station men; that among these are life, liberty and the pursuit of happiness—except furnishing municipalities with electric lights; that to secure these rights and also municipal ownership—government was instituted among men. No! Government, whether national, State or municipal, was instituted for the purpose of *protection* and not *production*. It would be just as reasonable for the city to enter any pursuit, such as

farming, or as a grocer, or keep a sawmill to saw its own material for sidewalks or paving, or manufacture shoes for its citizens, or run a saloon for the profit there is in it, as for it to enter the field of lighting. Just as sure as a nation becomes a commercial producer, competing against its own citizens, just so sure will the seeds of its own disintegration be sown.

Municipal ownership is a source of danger to the commonwealth, in that it affords a great opportunity for fraud. Municipal corruption is so common and so well known that it needs no argument to prove the danger of opening a new avenue of power in the hands of unprincipled public officials. In this business there are a number of important, and ought to be well salaried, offices, which can be used to great advantage by political manipulators to further their own ends to the detriment of the city. In the State of Michigan one political party had been in power for thirty-four years until 1891. A member of the old party was elected to the Senate and introduced a bill to benefit Coldwater, Michigan, and this has been the Mecca of the municipal advocates ever since. It has been the oasis in the desert where they could get sweet morsels to roll under their tongues to advocate the scheme of municipal ownership. I venture to say that more than a score of towns and cities have charged up expenses for the examination of this delectable plant, and from their own printed statements I am willing to qualify that the figures are not as they should be made. Reports come from Grand Haven, Michigan, that through political influence a competent electrical corps has been discharged to make room for inexperienced friends of the "powers that be". "To the victor belong the spoils"

is a policy followed with unswerving fidelity by a great many city officials. Scandals from our great cities in regard to employés, inspectors, officials and boodle aldermen, should teach us to avoid throwing this enterprise, involving hundreds of thousands of dollars, and positions of the utmost importance to the city, into the maelstrom of municipal politics.

Municipal ownership is unjust to the electrical plant now in the field. The central station man has, through his industry, ingenuity and executive ability, built up a large enterprise. The city has invited him to invest thousands of dollars, not only of his own money, but also the money of its own citizens, with no immediate show of dividends, and, in some cases, barely sufficient income to pay the running expenses and interest on the bonds during a period that will amount from one-half to the whole of the average amount of time allowed for depreciation of the plant. The central station man during this time has been harrassed with the anxiety of meeting the fixed charges, maintaining the credit, providing a reserve fund to meet loss by fire, wind storms and burned-up apparatus, and cheering up despondent stockholders who have nothing to show for their money but the rosy-hued prospect that, at some time in the near future, there will be an adequate dividend to compensate them for their risk, and now, when these hopes are about to be realized, in a modest degree, they are confronted by municipal ownership. He must either compete with the city—which, through ignorance, will furnish lights below cost—or sell out. The latter proposition is impossible, for he can not hope to dispose of a plant that has depreciated fifty or seventy-five per cent without great loss, therefore he is compelled to continue in business with his former heaviest consumer,

now his strongest competitor, with the prospect of having to renew his plant within a very short time, at a heavy expense, and knowing full well that there is room for but one paying plant in a city of that size. Such conduct on the part of the city amounts to the indirect confiscation of property; obtaining a competent and effective service for years without profit, holding out the alluring representations of a future gain.

Municipal ownership is unjust to the taxpayer. That through ignorance or willful errors in keeping accounts it is certainly true, in most cases, that lights are furnished to the city and private patrons at a loss, and the deficits charged to some other accounts. Very few of its citizens are able to take the lights at the reduced price, for the great majority of its citizens are day laborers, who are paying for their homes, and can not afford to take the lights even at any price, but who eventually must help to carry the burden of the ever-increasing loss, thus making the many help pay for the luxuries of the few. The City Clerk of Hamilton, Ohio, utters a dismal wail, recorded in the *Electrical Engineer*. He says: "Hamilton, of all the cities in the United States, is the most afflicted with the municipal ownership craze, and, having had its fill on theory, is now reaching the result under adverse circumstances. We are deluded in the belief that we have cheap water, cheap gas and electric lights, but when we add to these luxuries the fact that we have so raised the rate of municipal taxation until it has become burdensome, and then compare with other cities of our size, we are not so well off as we think we are. We are taxed to pay the interest on the gas-works and the electric light plant, as well as to provide for the redemption of the bonds, and we are also

taxed for the purpose of lighting the corporation, which is nothing more than a double taxation." Municipal ownership has cost the city $575,000. It is reported that an order has been made to discontinue the electric lights, on account of lack of funds. This has been a very expensive experience for Hamilton, and the taxpayer who has burned nothing but an oil lamp now helps to pay the bill.

The result, in most cases, will be less efficient service than under the competitive system. Central station men who have been in the business for a long time, and who have had years of experience, are, without doubt, the most competent to give the best service of the times. He surrounds himself with expert electricians and a corps of able assistants who have been educated in the business and retain their position by the strictest attention to duty. He is continually devising means for improving his service, not only in employés, but also in the latest improved machinery. On the other hand, municipalities change their officials frequently, and new men take control. Councilmen who oftentimes are not even good business men, and have no knowledge of apparatus and electrical affairs, pass on the purchasing of supplies and the competency of electricians and engineers, deposing experienced incumbents and apportioning political plums to friends of but ordinary ability. The men now in control attempt to compete with electrical experts and competent engineers of long experience, and about the time when they are beginning to understand their plant and how to save loss—in a year, or possibly two—the Council changes, and they must step down to make way for those of. even less ability. Again, in smaller cities councilmen are often elected on the single issue of economy, and in order to fulfill the

expectations of their constituents, they must cut expenses. The first attack is made on the official salaries, which results in filling responsible positions with inefficient men. Experts can not afford to educate themselves for positions commanding low salaries and subject to the vicissitudes of municipal politics, and we all know too well the cheap men in this business are the most expensive. Then, again, the economical councilmen will object to improving the plant, which will require vast sums in replacing that which has but lately cost so much, and for which they have not as yet finished paying. This is especially so if the improvements are demanded in a time of financial depression, and when taxes are already too high. Electrical plants, of all apparatus, are the most liable to be out of date, as in this class of machinery improvements are sudden and extremely radical, and what to-day is the best that can be bought, to-morrow, next month, or next year, is nothing but scrap iron if placed on the market. City Councils do not realize this, and in nine cases out of ten, would refuse to appropriate the necessary funds for the needed improvements, and, as a consequence, their antequated machinery, combined with inexperienced management, gives the city the meanest service for the highest price.

The glowing reports from cities that are experimenting with this question are unreliable and misleading, except to the electrical profession. In some cases, where the plant is new and there is no perceptible depreciation, and where they have providentially escaped accident or disaster, no doubt these statistics are honestly, though ignorantly, compiled, deceiving the taxpayer into the belief that their venture is a glorious success. The engineer's salary and the coal bill are

often charged to the water department, and the water consumer helps pay the electric light bill.

In most instances the item of interest on the outstanding bonds is charged instead of interest on the entire plant, and four per cent depreciation is charged, whereas from ten per cent to fifteen per cent should be the rate. In some cases losses by fire are not accounted for; in others accidents are never charged. The loss to the city of the taxes that would be paid in by a private corporation is not computed, and in a great many cases the accounts are so mingled with other departments that it is impossible for even the officials themselves to tell how much the lights for street purposes cost the city. The chairman of the Special Committee of the Municipal and Opposition Ownership, in his report to the Northwestern Electrical Association, says: "We have endeavored to investigate the results obtained in the municipal plants already established, but find that this can not be properly done, except by sending a capable representative to these plants. We have written for regular city reports, and have sent out blanks requesting answers to a number of questions asked. We find that, in the majority of instances, the expense report, as covering the cost of electric lighting, does not cover such cost, as is evidenced by finding electric light expenses charged under separate heads, and in but few instances does the city figure anything against the plant for interest, depreciation, taxes, water rent, office rent, management, fire insurance, water insurance, employers' liability insurance and general risk. It is needless to say that, without including but a portion of the expense of conducting an electric light plant, they can send out reports that look very inviting to other cities that are paying a fair rate for lighting

their streets and houses. The easiest way to demonstrate the fallacy of this scheme is by making a personal investigation and determining just what portion of the expenses are omitted that should be figured against the cost of the city's expenses in operating their electric light plant."

I have personally visited Niles, Kalamazoo and South Haven, Michigan, and I know that these cities are paying more for their lights than their official reports show what they cost, and yet they are considered among the list of those who are successful with municipal lighting. The city of Detroit has probably the finest equipped plant in the State of Michigan, and operated under the most advantageous circumstances, and yet she pays $100 in round numbers per lamp for 1,483 lamps, under municipal ownership, while St. Joseph and Benton Harbor, under the relentless pressure of a private corporation, only pay $90, on an average, for sixty-two lamps. Tipton, Ohio, and Marquette, Michigan, had serious accidents, and the deluded taxpayer, with his eyes partly open, refuses to vote more money for such a hazardous enterprise. It is not every city that can boast of the advantages which South Norwalk, Connecticut, enjoys, and of which she should well be proud, in that she has an expert electrician and a retired army officer to guard her plant from the evils that have blighted most enterprises, and, no doubt, to their efficient services is due the momentary success attributed to that municipal plant (I am informed, however, that their services are free to the city); but in the great majority of cases the city is not so favored, and the central station man, by his well earned knowledge and education in the profession, by his intimate acquaintance with the plant, and by the rigid economy that only comes from long

experience, is enabled to furnish the city with the most efficient service, at the same price, or even less, than it actually costs the city to produce its own light, and yet save for himself a reasonable profit for his enterprise.

At this present writing, however, municipal lighting has not passed through its most dangerous period, and it is difficult to predict its final result. It is now but at the dawn of its existence, but a December day will be long in comparison with the life it has to run, for when bonds are to be redeemed, accidents befall the plant, and a depreciated plant is to be renewed, then comes the trying ordeal, and woe be to the city that has not provided against that day, but has wasted its substance in riotous living, for then it will be found to have nothing left for its existence but the husks of "Municipal Lighting".

It is to be hoped that each and every member of this association, and of every central station, will constitute himself into a committee of one to get reliable data concerning municipal ownership, and present it in a proper form to the thinking public of this country, and after a full and thorough examination by the voters and taxpayers in this broad land, I think the question will be effectually settled.

Thanking you for your attention, and hoping for your hearty co-operation in dealing with this all-important question, I respectfully submit this paper for your consideration.

DISCUSSION.

THE PRESIDENT: Mr. Bean's paper is before you for discussion.

MR. DOHERTY: I consider this subject a very, very serious one. I am out of the woods myself,

but I have had a little experience with it; Mr. Bean has, and several other members. I think it a matter that would warrant the attention of this association—their continued attention, rather; and the portion referring to the data furnished, except by sending a representative to the plant, I wish still further to corroborate. I have had some experience in that as former chairman of the Northwestern Electric Association. The city plants now in operation are, many of them, dismal failures, but every one of them sends out reports that look very inviting to other cities. I merely rose to urge that, although the paper may not have a great deal of discussion, the members treat it seriously, and continue the protection in this line that the association has already endeavored to provide.

Mr. Beggs: The remarks of Mr. Doherty prompt me to suggest taking a text from the President's remarks this morning, that he didn't think it necessary for an association of this kind to have a large surplus fund. It seems to me that there is no use to which the association could devote a part of its funds with greater advantage to the central station and lighting interests of the country than to employ an intelligent, painstaking expert to gather reliable data from a number of municipal plants in different sections of the country. As has been well stated in this paper, the data that are available, except in a very few cases, are unreliable in the extreme. I believe that the only municipal plant that has put forth a report that is entitled to any respect as to its credibility, is that of the City of Detroit; and certainly any central station manager here would be very glad indeed, I think, if he were running the central station in Detroit, to furnish their lighting at quite as low rates as they are getting now, and relieve them of all

the disasters that Brother Bean has suggested are likely to overtake them in the future in connection with their own investment. But, as I had occasion to say once before in this convention, I think the City of Detroit was entirely justified in doing what it did. It was driven to it. And, gentlemen, let us take a text from that ourselves. Do not compel the municipalities in which you are managing electric light plants to put in for their own protection the means of lighting themselves. I take two papers that have been presented here this afternoon, and I contrast them, and I would suggest that, from my standpoint, it would have been better if some of the things said in the paper read a little while ago had not been said. I refer to it now simply to suggest that in the paper read by Mr. Cahoon earlier in the afternoon session, the inference might be drawn that the balance of your business in many of these cities in which you are doing business is unprofitable, but it is made to show a profit because of your city contract. I refer you to the first page of Mr. Cahoon's paper. I desire to draw attention to that fact, because it is incumbent upon us who have large capital invested in different sections of this country to feel that we are doing what we can in a legitimate way to render unnecessary the exploitation of municipal plants by municipalities over the country; and, therefore, we should see how we can reduce the cost of producing electric current to such a price that we can show to a city that we can supply current because of having this expert knowledge, better knowledge of the conditions necessary to run a plant economically, than they can possibly have. But, unfortunately, many plants throughout the country have not done that; and, Mr. President, I have to suggest—I do

not think it desirable, possibly, that it should be known generally—but there are plants all over this country whose statistics I think it very evident are inaccurate, to put it in the most charitable sense, and I think we should have accurate figures from them; and these could only be obtained by sending an expert there, paid by this association, to get the figures. Let us know the facts; it is high time we had them.

THE PRESIDENT: Do you suggest an expert accountant, an expert electrician, or what kind of expert?

MR. BEGGS: Either one. We must have a man that knows enough about the expert side of it and likewise the commercial side of it, to get these figures.

THE PRESIDENT: Mr. Beggs, Judge Armstrong suggests, I think very fitly, that that motion come before our executive committee, which will be convened in a few minutes. It has been moved and seconded that a vote of thanks be tendered to Mr. W. Worth Bean for his very interesting and instructive paper. It is a matter that will come before our active members again in executive session, and it is certainly one of the most important subjects with which the central station man has to deal. I think Mr. Beggs has indicated in a certain way something like the action that may be taken, and we may take action also. My successor may decide to take action in other directions, and, at any rate, I think the association is fully alive to the necessity of protecting the central station interests, as referred to in my address this morning, from the various troubles that threaten them, and not only fully alive to the situation, but has reached the point when it is fully able to act, and act with force. I am quite sure we stand in a different position to-day, in that

regard, than we have done since I remember, or since I have been a member of the association, extending back a good many years, because I have had the honor of being an officer for the past six years.

The chair appoints Mr. Ayer, as the mover, Judge Armstrong and Senator Foster M. Voorhees, of Elizabeth, N. J., as members of the committee to draft a law providing for the punishment of the theft of electric current.

THE PRESIDENT: I have been handed the following telegram:

"FORT MONROE, VA., June 7th, 1897.

"GEORGE F. PORTER,

"Secretary National Electric Light Association,

"International Hotel, Niagara Falls, N. Y.

"If not decided on your next meeting place, would like to have you arrange to convene at the Chamberlin, Old Point Comfort, Va. Master Car Builders and Master Mechanics in session here now. Hotel large enough to accommodate all of your convention. Large hall for holding your meetings. Everything on broad gauge. Would be pleased to have you.

"GEORGE W. SWEET, Manager."

I would suggest that this, like the other invitations, be referred to the executive committee, to be acted upon at the proper time. If it is your pleasure, we will refer this to the executive committee.

THE PRESIDENT: Gentlemen, the general proceedings will now be adjourned for this afternoon, and the executive session, composed only of active members of the association, will now convene.

I might say that from now until six or seven o'clock every delegate to the convention—active, associate, honorary or otherwise—is invited to visit the power house of the Niagara Power Company, and those of you who are not going to attend the executive session as active members, can proceed there now, and the active members will follow later on, after the executive session is over.

Judge Armstrong: Before our associate members leave, I would ask whether there is any other matter that you want to have come up this afternoon. While we are required, as I understand it, to give up the time at the close of each day to an executive session, I would, barring there being some other matter to come up, as we all want to go to the power house, move that the executive session be continued.

The President: I would suggest that we call the executive session, and it is within their province to adjourn, if they so desire.

Adjourned to executive session.

Mr. White then read his paper, as follows:

## THE NIAGARA-BUFFALO TRANSMISSION LINE

*Members of the National Electric Light Association and Its Guests, Ladies and Gentlemen:*

Before taking up the subject of this paper as given on the programme of this meeting, I crave your attention to a few words of apology, or, more properly speaking, of explanation. Some weeks ago, I notified the president and secretary of your association that it would be impossible for me to comply with their courteous request to prepare a paper on the Niagara-Buffalo Transmission Line, for several reasons, principal among which were the facts that, up to date, no measurements had been made to determine the exact capacity, induction, power factor, efficiency, or other similar attributes of the line, and that I was so occupied with an unprecedented amount of work in connection with my regular duties as to make it impracticable to find time to arrange in presentable form even the few facts obtainable with reference to this line. You can readily imagine my surprise, therefore, upon receiving the programme of this meeting a few days since, to see that the mere fact that there was nothing to say on this subject, deserving the attention of this association, had been disregarded in making up the schedule of these sessions. Under these circumstances, the blame for occupying the time of this meeting with facts too well known and too dry to deserve its attention, must attach to your officers.

The possibilities of the utilization of the almost infinite power of the mighty cataract whose thunders are audible from this building, has been dreamed of and written about ever since the days when the old French monks first attempted to convert the Indians living in this and more western regions.

A few days ago, I received a letter from Mr. Silas P. Dutcher, formerly Commissioner of Public Works of the State of New York, in which he dwelt on his personal recollections of the predictions as to the useful development of this power which the elder Roebling was wont to make some forty-six years ago, while erecting the first suspension bridge over Niagara River, the successful completion of which did so much toward securing recognition of American engineering ability as belonging to the world's front rank. This letter spoke also of the fondness with which former State Engineer Evershed was accustomed to dwell upon the possible development of Niagara's tremendous and untiring energy. A most fitting and enduring tribute to this same engineer (Mr. Evershed) is to be seen in the splendid plant of the Niagara Falls Power Company, some of his fundamental ideas as to its hydraulic development having been adopted by the Cataract Construction Company. This letter, written by the President of one of Brooklyn's most influential trust companies, illustrates the fact that we are living in a utilitarian age, and that others than engineers and manufacturers of machinery are interested in such developments as have for some years been going on in this neighborhood.

The character of this work, as exemplified in the power house, switchboard, and other details of the plant of the Niagara Falls Power Company, is such as to deserve the thanks of this association and of all

others interested in electrical development, on the ground that such working exhibits of high-grade installations have a tendency to raise the standard of all future work.

The poetic, imaginative and prophetic features of a transmission line from Niagara Falls to Buffalo and more distant points, have been thoroughly amplified and beautifully expressed, not only by such famous engineers as those above mentioned, but by such eminent men in our profession as Dr. Sellers, Mr. S. Dana Greene, Mr. T. C. Martin, in his lecture, "Niagara on Tap," as well as by numerous members of the technical and general press. These features will doubtless be most aptly illustrated, both in metaphor and on canvas, by the eminent electrical engineer of the Cataract Construction Company in his lecture this evening, so that no attempt whatever has been made in collating this hasty sketch to accomplish the impossible task of vying with these gentlemen, even in a small way, by the slightest attempt at the imaginative.

My first personal knowledge as to the then proposed transmission line between Niagara Falls and Buffalo, dates from the autumn of 1894, when the White-Crosby Company was asked to prepare and submit detailed plans, specifications and proposals for its construction. It was then found that the engineers of the Westinghouse and General Electric Companies had both recommended the construction of circuits of three wires, adapted to the three-phase system, each wire having an area of about 330,000 circular mils. Beyond this, no definite plans had then been determined upon. The engineers of the Cataract Construction Company at that time considered it advisable to have the line built entirely of iron poles,

and detailed drawings and specifications were accordingly prepared and submitted, showing alternative plans. The first included two entirely independent lines of iron poles, not less than forty feet long, weighing something over 2,000 pounds each. The second consisted of lines of poles of about the same height, weighing 1,000 pounds each, set in pairs and tied together by deep trusses, which served both as braces against the terrific wind storms that sometimes sweep across Lake Erie, and as a means of carrying part of the wires. A steel truss, fulfilling admirably this double function, was designed, which weighed about 600 pounds; the company's right of way being about thirty feet wide, and the lines of poles located fifteen feet between centers. Several wooden trusses were designed for the same purpose, but, while better from an electrical standpoint, these were all so clumsy in comparison with the iron poles that preference was given to the steel truss. Various designs of poles were considered, including several built up from "rolled shapes," final preference being given to plain tubular poles, on account of their ability to withstand equally rains from all directions, their appearance, and the ease with which they can be kept painted.

Numerous designs for cross arms were also considered, including those made from "rolled shapes," composite arms (part wood and part steel), and those made entirely of cast iron or of wood. The latter two were preferred, on account of the ease with which they could be designed to accommodate either wood or iron pins.

In determining the details for these alternative plans, it was assumed that poles would be set in concrete and spaced one hundred feet apart; that each wire would weigh one pound per linear foot; that the

three wires composing each circuit were to be placed at the corners of an equilateral triangle having sides at least three feet long, and that the lateral strength of the line was to be not less than three times the forces produced by wind acting with a pressure, at right angles with the direction of the lines, equal to thirty pounds per square foot on the projected surface of the poles, arms, insulators and wires when the latter were covered with a coating of ice one-half inch thick. As a matter of fact, the heat generated by the current passing through the wires, together with the static effect tending to repel all particles of moisture coming in contact with the wires (this effect being quite noticeable on a 10,000-volt line), would combine to prevent the formation of any such coat of ice unless at a time when current was off the line. Any error thus introduced was on the safe side, and consequently not objectionable.

Full proposals, with detailed plans and specifications for the construction above outlined, were submitted October 11th, 1894, and the amended proposition for carrying out the construction on the same general lines was submitted March 13th, 1895. Nothing further developed in the matter until June, 1896, when new proposals were asked for the construction of the line, on the assumption that white cedar instead of iron poles should be used throughout. Such proposal was submitted June 18th, and was accepted some days later. In working out the details of the line as built, the same general assumed data above given were used.

When the route for the line was finally determined upon, its length was found to exceed twenty-seven miles, instead of being twenty-five miles as previously assumed, and the area of the wire was consequently

increased from 330,000 to 350,000 circular mils. The wire actually erected is composed of nineteen strands, having a combined area of full 350,000 circular mils, and weighs nearly 6,000 pounds per mile.

In designing a transmission line, the three most important factors probably are:

1st. Its ability to carry its full load continuously and without interruption.

2d. Cost.

3d. Efficiency.

The first cost of power used to develop current for a transmission line is usually low; therefore the efficiency of the line is not of primary, although of great, importance. Those of us familiar with the development of the street railway motors have seen in practice an illustration of the fact that efficiency is not always a controlling factor. There has probably never been in general use another street railway motor so efficient as the Sprague Number Six, yet a distinct advance was made in sacrificing efficiency to mechanical strength, and in subjecting track joints to what at first appeared to be an unnecessary, and certainly to be deprecated, wear and tear, in order to decrease the interruption to traffic.

First cost, within reasonable limits, should always be considered secondary to good construction, so that you will probably concur in awarding first place, as a factor in problems of this nature, to the avoiding of interruptions. This is surely of primary importance in lighting work, and it is easy to conceive of circumstances where the unexpected shutting-off of power might have more serious, or, possibly, more fatal, results than could ever arise from sudden deprivation of light. Entering into this problem of sure and continuous operation, we have the same two fac-

tors entering that usually confront us in connection with any electrical installation; namely, insulation and mechanical strength. In low-tension plants of all kinds, the insulation is usually accomplished with ease, and any probable defects are likely to be of minor importance, but, on such a line as that under discussion, the importance of these two factors is practically equal, and they are mutually interdependent. This has been practically illustrated by the experience afforded by the present line. With units of an ordinary size, a short circuit on a line carrying 10,000 volts, even if through a defective insulator, a wooden cross arm and a wooden pole, would make itself manifest at the power station by the opening of a circuit breaker, the blowing of a fuse, or some similar method. With the huge generators that furnish power for the line, the effects are different. Of what importance to a 5,000-horse-power dynamo is the current that would leak down a wooden pole, even when wet? Nevertheless, this same current is sufficient to char or burn the pin under a defective insulator. During one night last fall, while an attempt was being made to operate the line on temporary insulators,—the best obtainable at the time—the ends of no less than five of the large cross arms used on this line were burned entirely off, and this, too, without any manifestation having been made at the station that anything unusual had occurred. This naturally raises the questions whether it is possible to procure insulators that can be depended upon to maintain the insulation on a circuit carrying 10,000 volts or over, and whether it is not good practice to have fewer poles, and, consequently, fewer weak spots in the form of insulators. There are two sides to this question, and both deserve serious consideration in designing any transmission line. Let us assume that

poles are set one hundred feet apart, and allow a sag in wires between supports of twenty inches, or one-sixtieth of the length of the span. We find that the area of the wire in use on this line is .267 of one square inch, and that its tensile strength, even assuming a high value for soft copper, is about 10,000 pounds. Allowing the same deflection,—one-sixtieth of the length of the span—this determines the maximum safe distance between poles as 178 feet, allowing a factor of safety of four, and shows that the cables might be expected to break if the span were lengthened to 712 feet, not allowing for wind pressure or extra load due to ice.

Assuming a tensile strength of 8,000 pounds per square inch for yellow pine, we find that the larger cross arms used on the line, which are twelve feet long and nearly five inches wide by six inches high, would support a load of 270 pounds on each end without bracing, and of 360 pounds on each end with the steel angle braces used, and this, too, with a factor of safety of ten—an unnecessary margin, when we consider that the arms are all specially selected heart, long-leaf Georgia pine. Similarly, these cross arms would have the same factor of safety carrying three power cables on each side with spans 177 feet long if without braces, and 266 feet long with braces. Besides giving this added strength, the braces used on this line prevent such vibration and oscillation as usually take place with the ordinary strap iron braces; such oscillation being the cause of many of the petty troubles on ordinary lines. These braces were each made from a single piece of steel angle, two and one-half inches by two inches by one-fourth inch, bent to shape and forming, when finished, a truss eighteen inches deep and five feet in extreme length, their

weight being a little over twenty pounds each. Assuming, again, that poles are set one hundred feet apart, we find that twelve wires, with cross arms, insulators, etc., would present an area to the wind aggregating about sixty-seven square feet, and that, consequently, each pole would be subjected to a side strain, when wind pressure was thirty pounds per square foot, of about 2,010 pounds. A sound fifty-foot cedar pole, eight inches diameter at top and eighteen inches diameter at butt, eight feet being rigidly in the ground, would be capable of withstanding, before breaking, a side pressure, near its top, of only about 4,900 pounds when a layer two inches thick had decayed around its circumference.

With spans of one hundred feet, the pole would therefore have a factor of safety of only about two and one-half inches when new, while the wires would have a factor of safety of about seven and the cross arms of about twenty-six. The advantages of having cross arms amply strong are so evident, and the possible reduction in cost such an insignificant part of any ordinary line carrying much copper, that it would seem foolish to reduce the size of these in order to bring their strength down to correspond with other parts of the line.

It is evident from the above that the weakest point of this line, mechanically, is the pole, in spite of the fact that, as advised by one of the prominent members of your executive committee, final decision was made in favor of spacing the poles seventy-five feet apart on straight, and proportionately closer on curved, parts of the route. The only reasonably safe and practicable method of decreasing the number of weak spots furnished by the insulators, would be to use poles larger than eight-inch tops, or to brace the

poles to withstand this wind strain. Fifty-foot poles, having tops greater than eight inches, are now hard to find, and although thirty-five-foot poles were used on a part of the company's private right of way, nevertheless, many fifty-foot, and even a few sixty-five-foot, poles were required to avoid obstructions and for crossing railroads and highways. The only feasible plan, therefore, would seem to be to brace the poles laterally, which can readily be done if set in pairs, but which would be very difficult to accomplish in a satisfactory manner with a single line. This naturally brings us back to the question, "Are insulators such insurmountably weak links in such a chain, and is it not possible to get insulators that can be depended upon even when supporting wires under a pressure of 10,000 volts?" This can be most satisfactorily answered by again narrating the experience with this line. During the past eight months, insulators have been sent to Niagara Falls by four of the works which are among the first six in this country in the production of porcelain for electrical use. Of a sample lot of ten received a few days ago for test from one of these factories, one had broken in transit, eight broke under the strain of electrical pressure varying from 16,000 to 36,000 volts, and the last broke under 40,000 volts' strain. This latter would seem to be a minimum safe test limit for any insulator expected to sustain a regular strain of 10,000 volts, and is a test that any mechanically-good, well-vitrified insulator of ordinary design will pass. As several previous lots from the same factory showed even poorer results, the manager of that company states that he hopes within a few weeks to be able to furnish insulators that will stand a 40,000-volt test. It is only fair to state that these insulators were of a smaller type than,

and different design from, those in use in the Niagara line. Several lots of somewhat similar insulators from another factory gave about the same results.

Several thousand insulators, of a diameter almost equal to the round type now on the line, but of a design somewhat different in details, were furnished by a third porcelain works. These were all supposed to have been tested, and to have successfully withstood a pressure of 40,000 volts at the factory before shipment. When, however, these were tested at Niagara Falls by Mr. Lincoln, the electrical superintendent of the Cataract Construction Company, it was found that a large majority of them broke down under a 40,000,-volt test, illustrating that a dry test, such as had previously been made, is useless for practical purposes. The method of test used at Niagara Falls was as follows: The insulators were set inverted in a shallow iron pan in lots of about twenty, the bottom of the pan being covered with an inch or two of water containing a little salt. A little of the same brine was poured into the pin-hole of each insulator, and into this was thrust a small piece of metal, such as an ordinary iron spike or the small, round, zinc rod from an ordinary sal-ammoniac battery, this being connected to one side of the testing circuit, the other side being connected to the pan containing the insulators. After the metal rod had been placed in the brine in the pin-hole of an insulator, the primary circuit of the testing transformer, specially built for the purpose, was closed, and, if the insulator was weak, this was quickly manifested by a series of sparks through the punctured porcelain. Experiments made with pure water and with brine showed that there was no difference in the results, but that any weakness was manifested a little more quickly with brine; besides which, the salt

imparted the characteristic bright sodium color to sparks otherwise almost colorless and difficult to detect.

As it was important that the line should be ready to deliver current by a specified date, the test was reduced on these insulators to 20,000 volts, and all that withstood this pressure were passed for temporary use. These insulators were later replaced by some of those now on the line, all of which successfully passed a 40,000-volt test made as above described. The temporary insulators illustrated the old saying that every rule has its exception, for when, after removal from the line, they were tested under 40,000-volt pressure, a solitary insulator, from a total of 1,150, was able to pass muster.

Of the insulators shipped by the fourth factory, and of the two types now on the line, about twenty-five to forty per cent were usually found to be defective, breaking down under 40,000 volts; this percentage decreasing in the last shipments received. It is, however, worthy of special note that since the last of the temporary insulators were removed from the line, there has not been one minute's suspension of current supply due to defective insulators. During this time, some three or four months, three insulators have been replaced, none of these being of the oval type. Two of these three had been broken while being put in place, and the third was broken by a stone or other missile. In all three cases, only the outer petticoat was broken, and the insulator continued to do satisfactory service until such time as it could be replaced without affecting the operation of the line. Apparently, therefore, it has been demonstrated that it is possible to secure insulators that are reliable. That there have been no greater troubles in the past from defective insulators, is probably due to the fact that

most of the large transmission plants in operation under high voltage, up to within a few months, have been in the far West, where a climate prevails very different from that natural to this immediate region.

In the above and other experiments with insulators, some interesting facts have been developed, and are worthy of note. The insulating strength of porcelain depends almost entirely on the thoroughness of its vitrification, and very little on its thickness; a thin china teacup having successfully withstood a pressure of 60,000 volts, while a coarse piece of porcelain two inches thick was readily pierced by 25,000 volts. It is, therefore, practically unnecessary to test electrically any insulator which, when broken, will not pass a good absorption test, using red ink or other fluid.

It is quite, if not entirely, impossible to puncture a glass insulator, even an ordinary pony telegraph insulator withstanding any pressure that can be applied, the last being determined by the pressure that will send an arc around the insulator. The objection to using glass insulators in the past has been due to the difficulty in getting a well annealed and mechanically strong insulator of such massive design as is needed for this work, and to the hydroscopic property of glass, which is not shared by porcelain. The first can unquestionably be overcome by care in manufacture. The importance of the second has probably been exaggerated in most calculations made in the past, due to an inadequate appreciation of the static effects of 10,000 volts in warding off snow-flakes and drops of rain, and, to a less extent, of the rapidity with which water falling on such insulators is evaporated by the heat of the current leaking over the surface. It is, consequently, reasonable to expect that the use of glass insulators for high-voltage lines will greatly

increase with improved manufacture. Meantime, any lines erected should have the best obtainable porcelain, and every insulator should be subjected to test.

Before closing, it is natural to ask, "Is the line as built a genuine success? Can it be depended on, and is it effective?" In answering, let me give briefly some of the facts. The line now in operation is over twenty-six miles long, of which the last 4,000 feet is under ground, the current being carried in lead-covered cables with rubber insulation, these having been drawn into terra-cotta duct conduit built especially as part of this line. These cables successfully withstood a test of 40,000 volts, are guaranteed for five years under working pressure up to 25,000 volts, and were punctured during test only by a pressure estimated by Mr. Lincoln as about 80,000 volts. They have given no trouble since current was first turned on the line, November 15th last, except at two imperfectly made joints. Except for the short time needed to repair one of these joints, there has not been a single shut-down chargeable to the transmission line itself since the last temporary insulators were removed, some three or four months ago. A number of interruptions to service have occurred during that time, due to derricks used on the work now being done on the Erie Canal hitting wires, undermining of poles and conduit by this work, and to allow new lightning arresters to be put in circuit at transformer houses. Except for these extraneous and unusual causes, the service has been perfect, with the slight exception noted above. One short interruption early last winter was due to the dead limb of a tree blowing across the wires, illustrating the fact that all trees should be cut down for some considerable distance on both sides of any high-voltage line. The line shows an insulation resistance of some

250,000 to 300,000 ohms on wet, and about 1,000,000 ohms on dry, days, this being between any one of the three wires and the ground, the insulation, therefore, varying from 6,000,000 to 25,000,000 ohms per mile of wire.

The actual working efficiency, as shown by the wattmeters in the low-tension alternating circuits at Niagara, and the direct-current 500-volt circuit at Buffalo, was 79.6 per cent, this being for a considerable period and a fluctuating load. This efficiency included loss in step-up transformers, line, step-down and rotary transformers. It is probable that any decrease in this, due to greater line loss with larger load, would, to a considerable extent, at least, be offset by increased efficiency of transformers. In view of these figures, we hope you will feel warranted in indorsing the opinion that Niagara power *is now* being satisfactorily delivered in Buffalo.

One of the questions often asked is why this entire line was not placed under ground. One of the principal reasons was that the line of twelve wires, having a capacity of 20,000 horse-power, would cost, irrespective of right of way, fully one million and a quarter of dollars, if under ground, and only about one-third of that amount over head, making a difference in interest charge.

Of such total costs, about twenty per cent would cover cost of conduit, complete, including manholes, the remaining eighty per cent being lead-covered cables.

Of the overhead construction cost, slightly over eighty per cent is bare copper wire; less than ten per cent covers poles set in place and about three per cent covers insulators.

It is probable, therefore, that the depreciation of

the lead-covered cables' will greatly exceed that on pole line, the first cost being some thirty times as great and the depreciation of the bare copper being negligible. Aside from this, experience to date has not demonstrated that the underground line would be more reliable, which alone could justify the increased depreciation and interest charge.

As a final deduction, it seems reasonably certain that it is now possible to build either overhead or underground transmission lines—even in regions subject to much cold, damp weather—capable of carrying current at 10,000 volts, or higher, pressure, which can be operated with efficiency and every assurance of uninterrupted service.

DISCUSSION

THE PRESIDENT: Gentlemen, this paper is now open for discussion.

MR. SEELY: I should like to ask Mr. White whether it is necessary to shut off the current when they replace their insulators?

MR. WHITE: Some insulators have been changed without shutting down, and it is quite practicable to do that where the wire has not been tied in. Where it has been tied in, unless on a very dry day, I would rather somebody else should attempt to replace the insulators with the current on. But I know of other 10,000-volt lines where it is done, and by having a large stool, mounted on four porcelain insulators, on which a ladder can be placed, it will be entirely possible for a man to get up to the line and replace the insulator. The only trouble about it is that with 10,000 volts the capacity of a man is sufficient to absorb considerable spark, and if the man were nervous he might get shock enough to knock him off the

ladder, so it is not a pleasant task; but it is entirely possible of accomplishment. We did replace a number of insulators where the wire had not been tied, by lifting the wire on the top of another insulator which was mounted on a long stick, and then replacing the insulator and letting the wire come back into place. In actual construction, the wire, as you probably know, was not placed at the corners of a triangle, but the line was divided into six sections, and at five points the three wires were given a twist, so that for two of the six sections each of the three wires occupied relatively the position of one, two and three, and this counteracts to a considerable extent the induction that would otherwise be exerted.

Mr. Bean: I understood, Mr. White, that it was necessary to cut the trees for a certain distance on each side of the line.

Mr. White: Yes; I should say that, under all circumstances where it is possible, unless the right of way cost too much or is too expensive, it ought to be done, so that no falling trees can reach the line. Of course, that would make it absolutely safe. But from that limit, what is feasible would be determined largely by the cost of getting the right to cut down trees, and would be advisable, certainly thirty or forty feet on each side, and more if possible.

Mr. Seely: I presume time alone will demonstrate the efficiency of the 30,000 or 40,000-volt tests applied to the insulators?

Mr. White: Yes; of course there are no data as to that. But the mere fact that not a single insulator has broken down during this time, is pretty good evidence. With the other insulators which were put up temporarily, the depreciation on the line was quite rapid, as mentioned in the paper. We used to have

cross arms burn off quite frequently, and that came from the fact that, although these insulators had stood the 20,000-volt test, and there were only 10,000 on the line, yet enough rain would strike them to gradually moisten the porcelain, and, of course, as they absorbed this moisture, the insulating properties would drop down to so small a value that they allowed the current to go through until it burned off the cross arms with the arc that would form. That, of course, would break the contact, and the arc would stop of its own free will. In regard to these two insulators, I might say that the probable cause why this one (indicating) has stood more than the other, is that it is a little stronger mechanically, and the three breaks were all due to some mechanical trouble, and it is probable that the difference is due only to that mechanical strength. The advantage that those have carrying the rain over and letting it drop down to the side of the cross arm is perhaps of some value, although not as yet demonstrated to be of any great importance. The only place where we have had any illustration of an advantage that it might be, was where a tie wire, after being twisted around the insulator, was carried down toward the cross arm, and the arm was burned by the current starting, following a drop of rain from the end of the tie wire to the arm, and thus burning the arm, and for that reason it might be better to have the rain carried off to the end, and then it will drop clear of the arm to the ground. But probably that is not of any great importance.

MR. DOHERTY: I should like to ask Mr. White how many lightning arresters they distribute.

MR. WHITE: The lightning arrester problem is still in process of being solved, and it is largely in

the experimental stage. There are very few of them on the line. We protected the line from lightning as much as we could by running two barbed fence wires on top of the poles, one carried on the outer cross arm by an iron pin eighteen inches long and one inch in diameter, which went through the cross arm, and had a little fork at the top supporting the barbed fence wire; a second, similar wire was carried on the peak of the pole, the poles all being roofed, and a third is intended to be put up on the other side of the cross arm when additional wires are put up. Every fifth pole, these barbed fence wires are grounded with a number six copper wire running to the bottom of the pole and being coiled there, so that we can expect discharges to be carried off by these numerous points without accumulating sufficiently to give a lightning stroke. But the lightning arresters themselves are placed only at the transformer houses up to date; and these have given some trouble, so that, probably, none will be placed on the line until something has been put in the transformer houses that is perfectly satisfactory.

MR. SEELY: I should assume, Mr. White, that it would be preferable to place the wires under ground entirely. It would cost, probably, according to your figures, about $800,000 more.

MR. WHITE: That would be forty dollars per horse power.

MR. SEELY: At the rate of forty dollars per horse power; yes. Then you have a permanent installation under ground; you are not troubled with the defects discovered with the overhead wires.

MR. WHITE: That view, of course, may be correct. But, as I stated in this paper, it has not been demonstrated up to date, from the fact that the only

trouble due to the line thus far was from a joint in the cable. There has been no trouble due to the insulators, and there are 4,000 feet under ground as against over twenty-four miles of insulators; so we have about thirty-five chances to one, so far as distance is concerned, of trouble with the overhead as compared with the underground.

LIEUTENANT S. DANA GREENE: It seems to me, Mr. President, that the question of lighting on a line is really the most serious one to be considered; that is, in considering the comparative advantages of the overhead and the underground lines. It is a fact that no tests that any manufacturing company of which I know can produce at their works, are at all indicative of the results to be obtained on the line here; and it has been found actually necessary for them, in testing lightning arresters and fuses, to bring the experimental apparatus to Niagara Falls and actually test it by short-circuiting the machines here. In other words, the effect of a short circuit with 5,000-horse-power generators on a 10,000-volt line is very different from anything obtained in ordinary use and practice. While it is probable that the lightning protection that has now been devised in the line will be sufficient to answer the purpose for the present, there will yet be always more or less risk from lightning until the wire is put underground. It seems to me that that is the evident conclusion one must arrive at; that is the weak point in the whole system at this time, and must be until these are finally put under ground.

MR. INSULL: Did I understand Mr. White to say that it would cost $600,000 more for a line to carry 20,000 horse power under ground?

MR. WHITE: It would cost about a million and a quarter, I estimate, for a line carrying 20,000 horse

power; that is, four series, three wires each, making twelve wires total, for a distance of twenty-seven miles; it would cost fully a million and a quarter with the lead-covered cable, of which four-fifths would be for lead-covered cable and one-fifth for conduit. That would mean sixty dollars per horse power, in other words, and it would cost about one-third of that amount over head, or twenty dollars per horse power.

MR. INSULL: Then the interest on it would form an important part of the cost?

MR. WHITE: If placed under ground at sixty dollars, the interest charge would be three dollars, allowing five per cent, and an additional amount at least equal to that would be allowed for depreciation, and probably a good deal more than that. It is hard to tell what the depreciation would be on lead-covered line under those circumstances, but five per cent would certainly be moderate; probably ten would be more nearly correct. In that case, the depreciation would be six dollars per horse power and interest three, allowing ten per cent depreciation, to be safe.

MR. INSULL: That would be a very important proportion. If you were going to sell power at twenty dollars, it would be thirty-three per cent of the gross receipts. On this question of lightning arresters, I should like to ask Mr. Greene whether it is not true that, in units up to 1,000 horse power, lightning arresters can be furnished that will carry a lightning discharge, and will, at the same time, interrupt short circuit of the dynamos without serious trouble. Of course, as he says, with 5,000 horse power it is a very serious matter to stop an arc after it has once formed, but up to 1,000 horse power it can be done more easily, and is probably possible.

LIEUTENANT GREEN: I think it may be possible,

but I do not think any company will guarantee a device to be an absolute protection against lightning, and, as the amount of power delivered in Buffalo increases, it seems to me that the success of the sale of power in Buffalo is going to depend very largely upon the absolute reliability of the service. It is possible, for instance, that the poles themselves might be struck and destroyed by lightning—might cause very serious danger to the line. Of course, the network which Mr. White described as having been placed on the top of the poles is a good protection. I do not think it can be said that it is an absolute protection against lightning under all conditions of stroke.

MR. INSULL: When I first saw this overhead line, what seemed to impress me particularly was the awful responsibility of running such high potential above ground. But the figures just given by Mr. White would seem to indicate that if the line were put under ground it would render transmission from here to Buffalo almost prohibitive. With triple compound-condensing engines, the cost, including real estate, installing, say, 20,000 horse power, would certainly be within $2,000,000—$100 per horse power. Now, if to convey the same amount of power it is going to cost sixty dollars per horse power for the underground system, if they ultimately have to go to underground work, it would seem to show that the cost of the installation here at the source of power, and the cost of the conveying power of the plant, would be so great as to render long-distance distribution, even to so short a distance as Buffalo is from Niagara, almost prohibitive. I do not imagine, from looking at the plant here, that it can be installed for much less than $100 a horse power. It would seem to me, therefore, that a long-distance power transmission plant, includ-

ing the underground conductors, would cost at least sixty per cent more than the steam plant to produce the best possible results from steam in the city of Buffalo.

MR. BEGGS: I think, Mr. President, that the paper read by Mr. White, and the discussion that has followed, should be very satisfactory to investors in local electric lighting plants, who, for a few years, have heard that their business was likely to be taken away from them by these long-distance transmission plants of very high potential. I have myself seriously questioned the great advantage that was to be derived at points very remote from these great sources of power, for the reasons that have now come out in this paper of Mr. White's, to which I have listened with a great deal of interest, and which I think we shall follow--those of us who are charged with the management of electric lighting properties, and, likewise, electric railway properties, as some of us are, and who are investors in them--with a great deal of interest to see the development. I heartily agree with the idea suggested by Mr. Insull, and I very seriously question whether even this great plant at Niagara Falls can compete with the modern steam plant fifty miles from Niagara Falls. I do not believe it possible; and yet it is hard for us even to imagine what the future developments of this long-distance transmission have in store. I have been called in by some friends within the last thirty days to look over a proposition submitted to them as capitalists and investors in this class of property, where it is proposed —and this is a serious proposition, and one that is under consideration at the present time, and the process of raising capital to install it now under way—to transmit, not the 10,000 volts which Mr. White has been discussing here, but to transmit 60,000 volts a

distance of sixty miles, and to transmit 40,000 horse power—the initial installation being 4,000 horse power—on a number four wire; and that is held out as a proposition, to carry this current and supplant the entire steam plant in a city of some 60,000 inhabitants. The only satisfaction of the electric lighting plant and the electric railway plant in the city where it is proposed to deliver this power, is that it is proposed to do it at about two-thirds of what it is now costing them to produce it. I think if they can realize that result, why, they had better take that end of it, without attempting to install the transmission plant themselves. I have had others of the same kind. There is a proposition in Pennsylvania to-day by some of my friends interested in electric lighting plants in which I am myself largely interested—a proposition to put at Conewago Falls, on the Susquehanna River, a large power-transmission plant, to carry power into the city of Baltimore ultimately, but to Port Deposit and the city of Harrisburg and certain other cities in Pennsylvania. They, I believe, have made some proposition that they would supply power at the city of Harrisburg at twenty dollars a horse power. I advised my friends to corral it all; simply to make a contract to take the entire amount that could be delivered and utilized there at that figure. But the point I want to make is that I do not think that those of us interested in central stations that may be menaced, as some of us have been, by these long-distance transmission plants,—I do not believe that we are in any serious danger. It is not a question of developing power, it is a question of transmitting; and the point that I raised some weeks ago, in a long day's discussion of this long-distance transmission in the far West, and the plant that has been dwelt upon here, is the

difficulty of insulation—of clearing a path for your line. You can readily realize what it means to do what Mr. White has suggested here, and which is absolutely necessary. You must have a clear right of way that will enable you to cut down all the trees that can possibly fall across your line. One might never fall there, but you cannot take the risk of its falling; therefore, you must clear away sufficiently to prevent the possibility of limbs falling in a storm, or a tree crossing your line. And I think that is the serious difficulty that these long-distance transmission plants are going to encounter in the use of overhead lines, while the underground conditions are prohibitive from two causes, as has been well brought out in this discussion: first, the initial cost of your line makes it prohibitive, and then the great depreciation, many of the elements of which are not known in these high potentials at all. Those of us who have been dealing with underground lines for eight or ten years, know that the item of depreciation on an underground line, even under moderate conditions, is very great indeed. So it would seem to be almost impracticable, from a commercial standpoint, to put lines under ground, and very difficult to maintain them over head.

Mr. White: On this question just spoken of by Mr. Beggs, it is almost certain that the localities are very few, and the circumstances must be very exceptional, that will support a transmission line fifty miles long. In the first place, it would be necessary to have an ideal water power—unusually good water power; and in the second place, a very high cost of fuel, or the power could be generated more cheaply by steam. But there are localities where plants of that kind would pay, and could earn, not only fair, but in some instances an extremely high, interest on

the cost, even for such long distances. The only part of this country, perhaps, where that would apply would be out in the Rocky Mountains, where in some regions wood is scarce and coal costs, perhaps, eleven dollars a ton. In such localities, the cost of maintaining the interest on a line even fifty miles long can well be afforded. But under ordinary circumstances, as Mr. Beggs states, power could probably be generated far more economically with a triple compound-condensing steam plant than it could be developed and carried fifty miles over head, and certainly decidedly more cheaply than it could be carried fifty miles under ground. In this line, taking Mr. Insull's suggestion as to the interest charge, it would certainly not be wise to entail a charge of perhaps ten dollars per horse power for depreciation and interest under ground as against two dollars per horse power for depreciation and interest over head, unless the former were absolutely necessary and it were found by experience that lightning occasioned such trouble that it could not be handled satisfactorily. I do not believe such is the case. As to the insulation, it is possible to have that satisfactorily arranged. I know a plant in Michigan, from which I had a report two or three weeks ago, that has been running all winter, and in a climate where there is a great deal of rain and snow, and they have had quite a severe winter, at least in the way of a good many storms. That plant has been shut down but once in four months, and that was on Sunday noon, when notice had been given to the customers that there would be a shutdown at noon the next day. The shutdown was for ten minutes, and it was to tighten the key on the water-wheel shaft. The plant has no duplicates; has only one generator, and no duplicate machinery of any

kind; and the only shutdown in four months was this one of ten minutes on Sunday noon to tighten the key in that shaft. So it is possible to run a plant satisfactorily and not have any trouble with it.

Mr. Steinmetz: I think it is dangerous to generalize too freely in such matters, and to state that it is or is not economical to transmit power fifty miles. It all depends on what the power is used for, as to whether the transmission is economical or not. The problem changes very greatly according to whether the transmission is used in a factory for twenty-four hours a day—a steady load—or whether it is used where the whole load is only an hour-a-day run, and the remainder is idle, and you have to pay the same price; that is, you have to pay for the maximum load continuously, and use it for only a very short time. And then there is the other question coming in—as to whether your railway network of the city depends upon continuous power, never shutting down under any circumstances, or whether you run into a continuous lighting system; whether you have a big storage battery, and when you send out a man to repair the line the storage battery carries you over the break. All these conditions change the problem very greatly, and you must investigate the individual case to see whether the steam-engine plant is the more economical, or the long-distance transmission, but you cannot lay down any general rules.

Mr. Scott: The question of lightning arresters is one of vital interest in long-distance lines. A little experience is worth a good deal of theory in this matter. In the plant at Telluride, Colorado, which has been in operation for some half dozen years, a great deal of difficulty was experienced with lightning during the first year. The lightning destroyed, with

great avidity, all the arresters that were sent there during the first season. The subject was gone into very carefully, and a new form of arrester was provided, and since that time there has been almost complete freedom from difficulty arising from lightning. While it is probable that there can never be absolute security from danger from lightning, just as there can never be absolute security from breaking of shafts or falling down of poles, yet lightning protection can be accomplished with the same co-efficient of safety that pertains to other apparatus. The original plant at Telluride was for 3,000 volts, and this has been increased to 10,000. The distribution extends over the mountains, and at some seasons the lightning is quite severe. The plant supplies stations distant from two and one-half to eighteen miles, in large number and widely distributed. There has been trouble from lightning. Some transformers were burned out, and careful investigation showed that the ground wire of the lightning arrester had become affected by some workmen or some change taking place. The experience at that plant has been such as to justify the statement that 10,000-volt transmission, through a country that is particularly susceptible to lightning disturbances, can be adequately protected.

Mr. White: I was very glad of the remarks of Mr. Steinmetz, calling attention to the well known fact that any problem of this kind is an engineering problem, and deserves solution and attention on its merits, irrespective of the general conditions and theories which may apply to other plants and do not apply to that, and I can best illustrate that, perhaps, by the result of some tests that we had made at Leadville, Colorado. We sent a man out there to make some investigation as to an electric power plant in

that region. He found that in some instances power was costing the miners as high as $2,000 per horse power for the actual indicated horse power used. This was a hoist, of course. In that region, and over in Cripple Creek, some investigations were made. A great many miners have hoists, and have their boilers heated and power on for twenty-four hours in the day, and perhaps they use it but once in thirty minutes, or once an hour, to hoist a load. But they require an engine and they require fuel for the whole twenty-four hours, and fuel there costs eleven or twelve dollars a ton delivered at the mines, and water costs seventy-five cents a barrel, and with the use of a ten or fifteen-horse-power engine, but a few minutes each hour, you can readily perceive that the figures would run up to a very high degree. Even with plants using a considerable amount of power, the cost is usually from $200 to $300 per horse power indicated. So there are cases where power can be transmitted fifty miles or more and allow a good profit.

MR. WALBANK: I should like to ask Mr. White if he has ever put up any steel or iron poles—has had any experience with them?

MR. WHITE: I presume Mr. Walbank means for long-transmission work?

MR. WALBANK: Yes, sir.

MR. WHITE: No; we have not. Our experience with iron poles has been on ordinary lighting or street-car work.

MR. WALBANK: In this Buffalo transmission, the poles are all of white cedar, I understood you?

MR. WHITE: Yes, sir.

MR. WALBANK: And cost about forty dollars per horse power?

MR. WHITE: Twenty dollars.

Mr. Walbank: Twenty-two miles?

Mr. White: Twenty-five.

Mr. Walbank: We have just constructed a steel pole line from Lachine Rapids into Montreal, and we constructed all of our line of steel poles; that is, we took a channel iron and cut it diagonally through, and then riveted the reverse ends so as to make it about eight inches at the top and twenty inches at the bottom; put two of these columns up and then latticed them together; and your wooden cross arms are almost identically the same as we have, but without any braces underneath; and we have, altogether, thirty-six wires on. Our poles are placed 108 feet centres, and they stand, probably, thirty feet high, including seven feet in the ground. They are bedded seven feet in concrete.

Mr. White: That ought to give very good construction.

Mr. Walbank: The way we tested the poles, we placed 200 pounds of pig iron on the top, with a fulcrum to take the place of the ground. Our pole line, complete, with wire, insulators, cross arms, and everything, will cost us, for a distance of 30,000 feet —for the complete line—about $92,000. We figured that for underground work it was going to cost over $300,000 to do the same thing with lead cable. We have not tested it practically yet, because it is now just about completed.

The President: I shall have to close this discussion now. It is very interesting, and I wish we had more time at our disposal. We have another very interesting paper, and I shall call upon the author presently. I am sure we are all very much indebted to Mr. White for the instructive paper that he prepared. I know personally that he put himself to a

supply business to take the bad customers with the good, and the author hopes to show in this paper that it is quite possible to devise a simple and equitable tariff by which a profit to the supply company, as nearly as is commercially practicable, is assured from every consumer; and, moreover, that only by adopting such a tariff of approximately *equal rates of profit* from all consumers can central station managers hope to get the use of electricity generally adopted for all the many purposes it naturally lends itself to.

The author also hopes to show that it is not only possible, but extremely easy, to do an enormously extended business in electricity supply in such a way as to yield substantial profits to the supply company, and at the same time to supply electricity to an ever-increasing number of consumers at rates which will insure large business, and in most cases to successfully compete with gas.

Hitherto the main governing idea among central station managers seems to have been that electricity must rely upon its superiority as regards cleanliness, convenience and healthiness over its competitors for lighting purposes. The author hopes to convince the members that, in one of the richest fields open to central supply stations, electricity can compete with its rivals, even as regards price.

### UNRECOGNIZED PROFITABLE FIELD FOR LARGE EXTENSIONS

Owing to the enormous development of the business of electricity supply for power transmission, for traction and other purposes, many central station managers have lately devoted most of their energies to the supply of electricity for those uses, and have

apparently assumed that they have already substantially secured the greater part of the lighting business they are likely to get in their districts. The author, on the contrary, firmly believes that there exists even a larger and more profitable field for electricity supply ready at hand in every town, waiting only to be tapped, and refers to the supply of light to the thousands of domestic lamps required by the middle classes in their homes, which are used regularly every day for several hours, summer and winter, and which, in many cases, can be replaced by electricity at the same price, or even less than the light now used, and at the same time yield substantial profit to the supply company.

This profitable domestic supply, which is largely used after business hours, need in no way interfere with the much-catered-for power supply, the value of which the author fully appreciates.

Another enormous field for profitable extensions is to be found in the smaller and lower classes of stores, saloons and business houses that trade until late in the evening. As these classes of consumers frequently live over their business premises, their use of artificial light is a very lengthy one; although their bills may be small, they form a most desirable class of possible consumers, and can be supplied at a rate that, although low enough to secure the business, will yet yield such a substantial profit as to far more than counterbalance the extra cost of connection and collection to such classes.

Central station managers are now seeking fresh markets and uses for electricity supply, neglecting the domestic lighting field, which has hardly yet been touched. This, the author considers, is mainly due to the habit that they have generally acquired, of

regarding consumers collectively instead of individually, and estimating the cost of supplying any one class to be the average cost of supplying all classes, thereby overlooking that it is quite possible that more profit may be derived from the supply of electricity to small long-hour consumers at a low rate than from the supply of large consumers, such as extensive stores, at a much higher rate.

### IMPORTANCE OF THE TARIFF QUESTION

The author doubts the possibility of much financial success attending the efforts of central station managers until they dismiss from their minds the idea that large consumers' bills necessarily mean large profits, as very frequently the reverse is the case. Although it seems a mere platitude to say that a small business with a large profit is better than a large business with a small profit, yet this would not appear to have been generally realized, if we are to judge by the great inducements frequently given in the matter of discounts off heavy bills to consumers, irrespective of whether the conditions under which their electricity has been supplied have yielded a profit or a loss, while very little inducement, if any, has been offered to the small consumer, who requires light for long hours, in order to tempt him to use electricity for lighting purposes.

The author trusts it will not be imagined that, because he has expressed such a keen appreciation of the small long-hour consumer, he does not appreciate the large consumer having the same qualification. His contention is that, if an equal rate of profit be charged to all consumers of every class and size, the field for profitable extension is practically boundless.

In this paper the writer has tried to confine himself solely to the commercial considerations which govern the profitable extension of supply stations, he being firmly of the opinion that, while engineers have been devoting vast energy and time to considerations of coal and plant economy, they have neglected the easiest of all means for reducing the cost of supplying the electricity—viz., the adjusting of the charges so as to offer great inducements to the profit-yielding consumers and to charge as high a rate as possible to the unprofitable ones; this will assuredly broaden out the average load curve of the station and increase the usefulness of the investment. Although in large stations the question of coal economy comes almost next in importance to that of the necessity for absolute reliability of supply, the paramount consideration must always be the arranging of the tariff so as to attract the most profitable classes of consumers. The raw materials of electricity supply—viz., coal, water and stores—have in many stations been brought down to a little over one cent per kilowatt hour, and all the resources of engineering, so far as we now know them, can only help us to make a fractional improvement on that small figure.

### EFFECTS OF VARIOUS METHODS OF CHARGING

It may be argued that if the principle of *equal rates of profit* from all consumers be carried into effect, it might result in a serious loss of revenue to the supply stations, owing to the large but short-hour consumers objecting to the higher rates thereby necessarily charged to them; in practice, this need not be feared, as consumers of that type are generally either unable to dispense with electricity or are in sufficiently good positions to be able to afford to

pay comparatively a high price for the luxury of having the best light procurable for a short time per day, or at irregular intervals. Moreover, any consumer discontinuing his supply for the reason that he was charged at a higher rate than his neighbors, would not necessarily be a loss to the supply company, as, unless he is a source of profit, the plant allocated to his wants could be better employed; in fact, it certainly would be greatly to the advantage of many stations having a uniform rate of charge if they were to disconnect some of their large short-hour consumers instead of increasing their capital in order to extend their plant.

A perfect answer to these short-hour consumers, who object to pay a higher rate than their long-hour neighbors, is that under no circumstances whatever ought their supply to involve a loss to the supply company or increase the charge on the more profitable classes, as it is obviously very sound commercial practice in every business, without exception, to encourage the profitable, even at the risk of losing some of the profitless, business.

American central station managers were among the first to recognize that the cost of supplying a given quantity of electricity depends, in nearly every case, far more on the time over which the supply is spread than on the quantity taken, and early saw the commercial unsoundness of indiscriminately supplying all consumers at the same fixed rate per lamp hour or kilowatt hour, regardless of the varying lengths of time over which the supply was spread; but they, with many others, have been deterred from changing their method of chaıging by the doubt as to whether a more equitable one could be successfully carried out in practice.

If it be theoretically sound that the cost of supplying electricity generally depends chiefly on the length of time the necessary plant and mains are used, it seems an obvious corollary that the charge for the supply should conform to the same law. The author hopes to show that this theoretically correct principle can be successfully carried out in practice to the great advantage of both the supply stations and the general public. He moreover contends that it is impossible for a general supply to be given at so low an average cost or price on any uniform basis of charge as it can be on an equitable sliding-scale tariff, as a uniform price necessitates the long-hour, or profit-yielding, consumers having to make up to the company the loss incurred in supplying the short-hour consumers; this must tend very greatly to limit the use of electricity by the long-hour consumers, and, further, to bring to the station a large and undesirable class, who are thereby enabled to get their supply at less than its cost, and surely means placing quite an unnecessary and unwise limit to the lowering of the price at which electricity can be profitably supplied.

If the principle of a sliding scale based upon the more or less prolonged use of the maximum demand is correct, then, on every consideration of practice and of policy, it should be applied to each consumer without distinction.

Uniform rates mean that, if high, they discourage the only class of business yielding profit; and if low, mean a heavy loss on supplying short-hour consumers, which they directly encourage. Moreover, a uniform rate can never be so low for the supply of electricity to long-hour consumers as charges on an equitable sliding-scale system.

The author hopes to prove, by the figures given later, that a uniform charge for electricity limits its use to the classes, and that it is only by the system of making the charges follow the same law as the costs that the masses can be reached. This limiting of the use of electricity to the select few is still more aggravated by the prevalent, but highly pernicious, system of only giving substantial discounts to large consumers, irrespective of their manner of consumption.

One would think, to judge from the load curves of many of the central stations charging on the uniform price system and giving discounts in proportion to the amount of the consumer's bill, that nine-tenths of the population went to bed about eight o'clock in the evening, or, in any case, did not require artificial light after that hour; yet the amount of light required from then until 11 or 12 p. m. must be immense, and, being a prolonged load on the central station, would be taken under the most favorable conditions for cheap supply. As a matter of fact, in such towns it will be generally found that consumers pay two lighting bills—one for electricity, which, by reason of the high uniform rate of charge, only is used in the short-hour lamps in conspicuous places, and another for gas or other illuminants, which are used in the long-hour burners, by reason of their lower price—yet the actual conditions under which these different lights are produced and supplied favor quite the reverse.

It is important to bear in mind that gas is considered good enough in a considerable proportion of the situations where artificial light is required, and competition with it, in such positions, must be on the basis of cost. The public freely admit that electric lighting is necessary for living rooms, offices, shops,

theatres and restaurants, but with electrical energy at a uniform price, or other form of restrictive tariff, they are apt to remain satisfied with gas in corridors, kitchens, bedrooms, girls' workrooms, etc.

Although there are very few men who, having studied the question of the cost of supplying electricity, will now deny that this has to be provided and delivered under essentially different conditions from those appertaining to the supply of commodities, such as gas and water, yet it is not by any means so generally recognized as the author thinks it must ultimately be, if the use of electricity is to become equally general, that these great differences in the methods of production and supply are so radical that they necessitate entirely different methods of charge.

Taking the cases of gas and electricity supply, in the former, owing to the low cost and efficiency of gas storage reservoirs, it may be taken as nearly correct that one consumer taking the same quantity of gas per annum that another does, but at quite a different maximum rate, will cost the gas company practically the same amount; whereas, with electricity, owing to the greater cost of, and unavoidable loss in, storage batteries, compared to the cost of a boiler and steam dynamo plant of equal maximum output, it can be shown that a kilowatt hour, consumed in, say, half an hour, may quite possibly cost the company nearly ten times as much as if the same consumption had been spread over ten hours in the same day, owing to the capital outlay and standing charges being so enormously greater in the first case compared with the second. Now the author challenges any one to prove that it can be either equitable or even commercially expedient to charge for these two equal quantities of electricity at the same rate per kilowatt hour. Moreover, he asserts

most emphatically that, unless the charges for these equal quantities vary in about the same ratio as their respective costs, the supply companies are seriously discouraging their very best consumers and actively encouraging the most undesirable class they can have, and so long as the many-hour user of light is expected to pay the cost of keeping plant standing idle for other people, so long will he stick to gas if he is in a small way, or prefer an isolated plant if he is wealthy.

### DISCOUNTS ON CONSUMPTION PER LAMP FIXED

It may be said that all this is very much like thrashing a dead donkey, as many managers have long ago introduced the system of giving discounts in proportion to the number of lamp hours consumed per lamp fixed per annum. However, the author's contention is that, although this is an honest attempt to solve the difficulty, the counting of the lamps and estimating their current-consuming capacity is only applicable to those stations that cater merely for street or similar lighting.

The author maintains that, for anything else than street lighting, this system must have a very pernicious effect on the development and extension of the supply business, for the following reasons :

Firstly, as the discount given is frequently *inversely* as the connected load (a strange method surely of encouraging the public to give a whole-hearted support to electric lighting), a consumer usually installs only those lamps he can use very freely, and, under this scale, the longer he runs them the larger will be his "bounty" in the shape of discounts; as he knows very well that if he fixes any less frequently used lights, his consumption per lamp, and, consequently, the discount given him, will decrease, so he stops

short of the number he would like to use, and electric lighting remains for him a luxury strictly confined between the limits of certain business or social requirements.

The economic disadvantage of this method of charging, then, is that it tends to contract the load curve and drive up the peak, which seem to the author fatal to this system. This restriction of the use of electricity must prevent the consumer's individual load curve being broadened out by the use of lamps that, although not used for many hours daily, yet are used at a time when many of the others are extinguished. It is obvious that the more generally a building is wired the more natural is it that a prolonged demand for current from the supply station should result. In domestic lighting and in competition with isolated plant supply, giving discounts only on lamps actually fixed is prohibitive; a domestic supply of light is very imperfect unless it can be had when and where required, and in both of these cases it seldom happens that anything like all the lamps are required to be lighted simultaneously. By this method of discounts, hotels and private residences, which afford probably the most profitable field for electricity supply, would be charged at a rate so high as to prohibit the general wiring of them, although, by their being generally wired, their load curves would be so spread out as to make them highly desirable consumers. This method of giving rebates must also prevent large business establishments from wiring their entire premises, although, probably, the lights would be used in the upper residential parts when those on the lower floors have been extinguished.

The second objection is that in practice the author maintains it is impossible, in a large business, to ascertain with sufficient accuracy throughout the year the wired capacity of all the consumers' premises. This is patent when we remember the largely varying capacity of lamps, the natural desire and unobjectionable habit of consumers changing the candle-power of their lamps to suit their varying requirements, and the temptation this system offers to fraud; furthermore, it is no more equitable to estimate a consumer's actual demand from his wired capacity than it is to rate a motor at its maximum possible output, irrespective of its actual current requirements.

The third great objection is the inexpediency and great expense of insisting upon the necessary domiciliary visits in all parts of private houses, hotels, etc., which this system requires. These visits are not only highly objectionable, so far as the consumers are concerned, by reason of the intrusion into the privacy of every part of the building, but, from the company's point of view, the expense entailed is very large, as the visits, to be of any use, must be frequent, and the time expended in counting lamps and noting their candle-power is very serious.

In one way or another the public has tolerated a good deal from electrical men—roof fixtures, for example—but the author's own experience has led him to the conviction that the best policy is to give them a good and steady supply on an encouraging tariff, to draw the revenue in due season, and otherwise trouble them as little as possible. The author can not think there is any finality in a tariff which makes it necessary for any one to intrude on the privacy of a man's premises for the purpose of checking his connected load.

Such a system, to put it mildly, leaves room for considerable inconvenience to both parties, and, as we elect to call electrical engineering a tolerably exact science nowadays, I think the time for domiciliary visits has gone by, as we can get all of the necessary figures in the neighborhood of the meter by the use of a suitable instrument.

Finally, no one can pretend to say that there is any real connection between the cost of supplying a large establishment, such as a hotel, and the scheduled number of lamps installed.

Fortunately, there is a much cheaper way of determining the consumers' true demand on the station for supply, consequently the true basis on which the charges should be made—viz., by measuring the greatest rate at which they usually require to be supplied with electricity.

Another system now very much in vogue, but having equally bad effects in preventing the profitable development of supply stations, is the unsound practice of charging a higher price for electricity consumed in lamps than in motors or other current-consuming apparatus, thus implying, for some reason, that the consumer who requires the use of the station generating plant at night should be debited with the whole of the standing charges incidental to keeping this plant ready, although the same plant may be equally used in the daytime to supply another consumer's motor. Surely both of these consumers ought, in common fairness, to share these necessary costs of keeping this plant ready. For a *reductio ad absurdum* of this practice, we have only to compare the relative profitableness of a basement user of lamps with that of an elevator motor, the former being the steadiest and longest consumer any manager can desire to have,

and the latter the most objectionable kind of short-time user of electricity.

THE ISOLATED PLANT QUESTION

In the author's opinion, one of the most profitable fields for extension lies in the displacement of isolated plants, which to-day are frequently a curse to the supply stations by requiring connections to the company's mains as a stand-by against accidents.

This practice forms one of the strongest reasons the author can quote for the necessity of charging each consumer the cost, as nearly as possible, of keeping a proportion of the plant and mains ready to supply him, just as much as it is necessary to make him pay in proportion to the quantity of electricity he consumes. The author maintains that the isolated plant question can, by a judicious tariff, be turned into a blessing, instead of a curse, and his experience leads him to believe that there should be little difficulty in obtaining practically the whole of the profitable part of this business as regular consumers, instead of irregular worries. By no other method than that of an equitable sliding scale can this particular and generally very profitable business be obtained. It is well known that isolated plants are generally only installed where the demand for electricity is of a lengthy nature, consequently they would form a most desirable class of consumers if their permanent supply could only be obtained.

That the result of an equitable sliding scale is to get this class of consumer on a central station supply, is shown in Brighton, England, where, since the sliding scale has been adopted, several valuable isolated plants have been secured to the supply station mains, and not a single new one has been installed in that town.

What is there fundamental in the organism of a central station which should enable it to furnish a block with electrical energy more favorably than can be done by means of an isolated plant? Clearly it is the diversity of the duty which may be performed by the central station.

The cost of a plant supplying a few premises whose requirements make their individual load diagrams pretty closely coincide, must clearly be higher than those of a station catering for a wide variety of demand, and the more diverse this demand in point of time, the greater the output of electrical energy for a given expenditure.

### VALUE TO SUPPLY COMPANY OF VARIED CLASSES OF CONSUMERS

Another excellent method of profitably extending the business of central supply stations, is catering for, as much as possible, different classes of consumers requiring electricity at varying hours, and on the same principle encouraging consumers to install lamps that will be used at different times of the day and night. This diverse supply in a town obviously means a much less plant capacity than would be the case were all the lamps required for the same purpose and at the same time. As an illustration it is only necessary to quote the two cases of a large, early-closing store and a theatre, or, as applied to the individual consumer, the public rooms and bedrooms of a hotel. In these cases the plant required to supply the store and theatre, or the hotel as a whole, would be generally much less than the sum of the requirements of the two classes. In the town of Brighton, where the actual demands of all the consumers are accurately known, and where the use of electricity is

very evenly divided between residences and stores, this diversity factor is now no less than one and one-half; or, in other words, if all the Brighton consumers were to require, simultaneously, their ordinary maximum supply (not their wired capacity), the generating plant of the station would have to be increased very nearly fifty per cent.

The consumers have a community of interests in flattening out the station load curve, and they are bound to do it on a tariff that encourages them to wire their premises throughout.

### BEST DIRECTIONS FOR ADDITIONAL CAPITAL OUTLAY

The importance of considering in which direction any additional capital of a supply company can be best spent, is also worthy of special study.

In the author's opinion, it is very much more important to run, very soon after the starting of the station, mains in all districts of the town in which artificial light is used late in the evening, although this may be in the districts of the poorer classes of consumers, than it is to spend it on coal-saving refinements, or in running large mains in districts occupied by immense early-closing stores or by the mansions of the wealthy; both classes being very expensive to supply, because of the short daily use made of the plant by the former, and the latter's frequent and lengthy absences from home, or the erratic nature of their demand.

The author would specially point out the true economy of a liberal supply of distributing mains, which can be made to serve the double purpose of supplying the street lamps as well as the general public. In this connection he questions very seriously the wisdom of the practice, resorted to by many

central station managers, of running special mains and systems for the sole supply of the public street lamps, as by so doing they needlessly increase the total cost of supplying the whole of the requirements of the district.

The author thinks that insisting on a high initial rate of charge per kilowatt hour, or lamp hour, being maintained to each consumer until the annual cost of getting the plant in readiness to supply his maximum wants has been covered, and then substantially reducing the charge for the subsequent consumption, forms the basis of a perfectly equitable tariff, applicable to all stations and conditions of supply.

### EXPLANATION OF TABLES AND CURVES

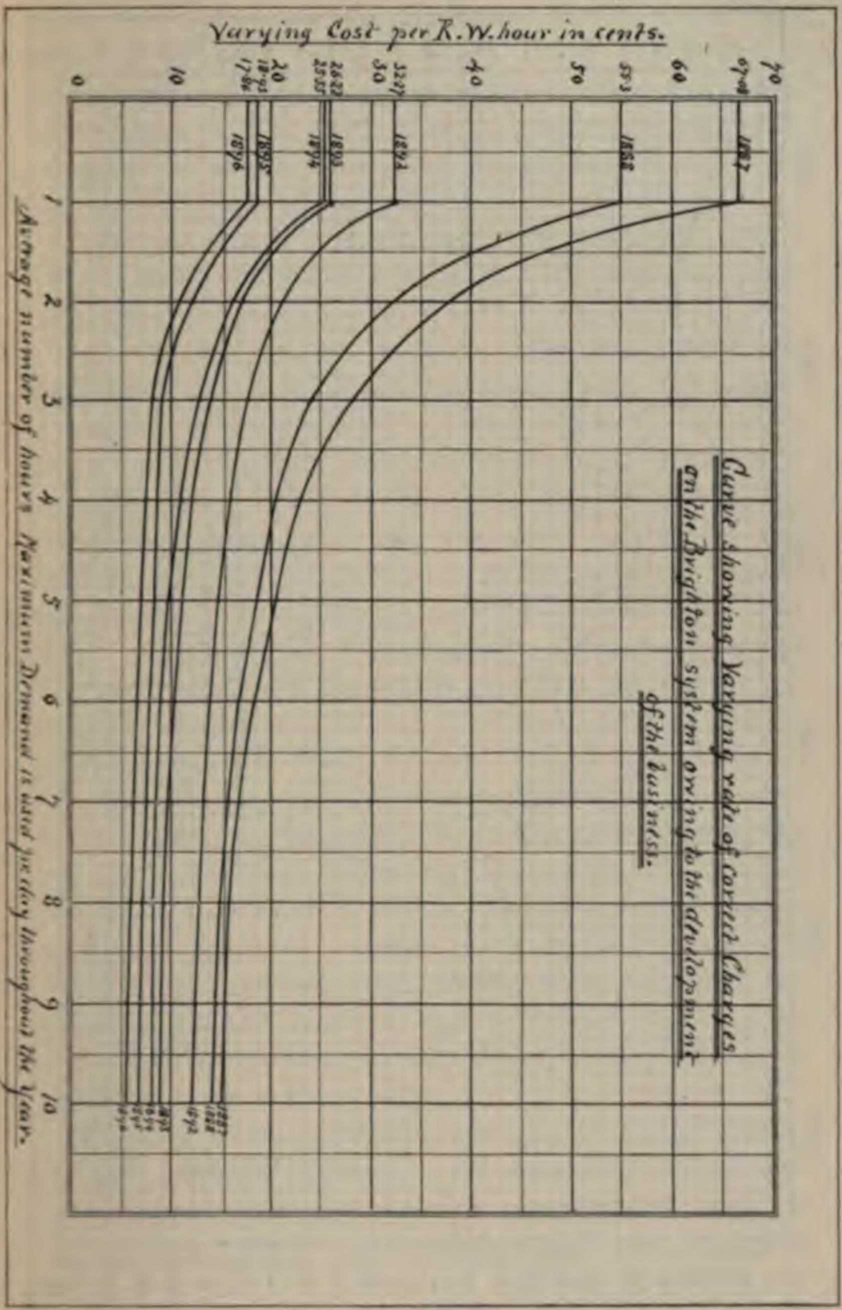
As the knowledge of the profit-earning capacity of any electricity supply station so obviously depends upon the correct method of determining the cost of supplying electricity, the author thinks that the accompanying tables, relating to the development of a supply station in the fairly representative English town of Brighton, will be found interesting.

He trusts that the results shown in the tables will be all the more useful to central station managers generally, as the profit-earning capacities of both the small pioneering and the large permanent stations erected in that town have been amply proved, and from which an uninterrupted supply of electricity to the public has been given; the economical working of the two stations has also been generally acknowledged, and, lastly, the efforts there to get electricity generally used have succeeded in a remarkable way, as shown by the consumption per inhabitant at Brighton being far and away ahead of that in any

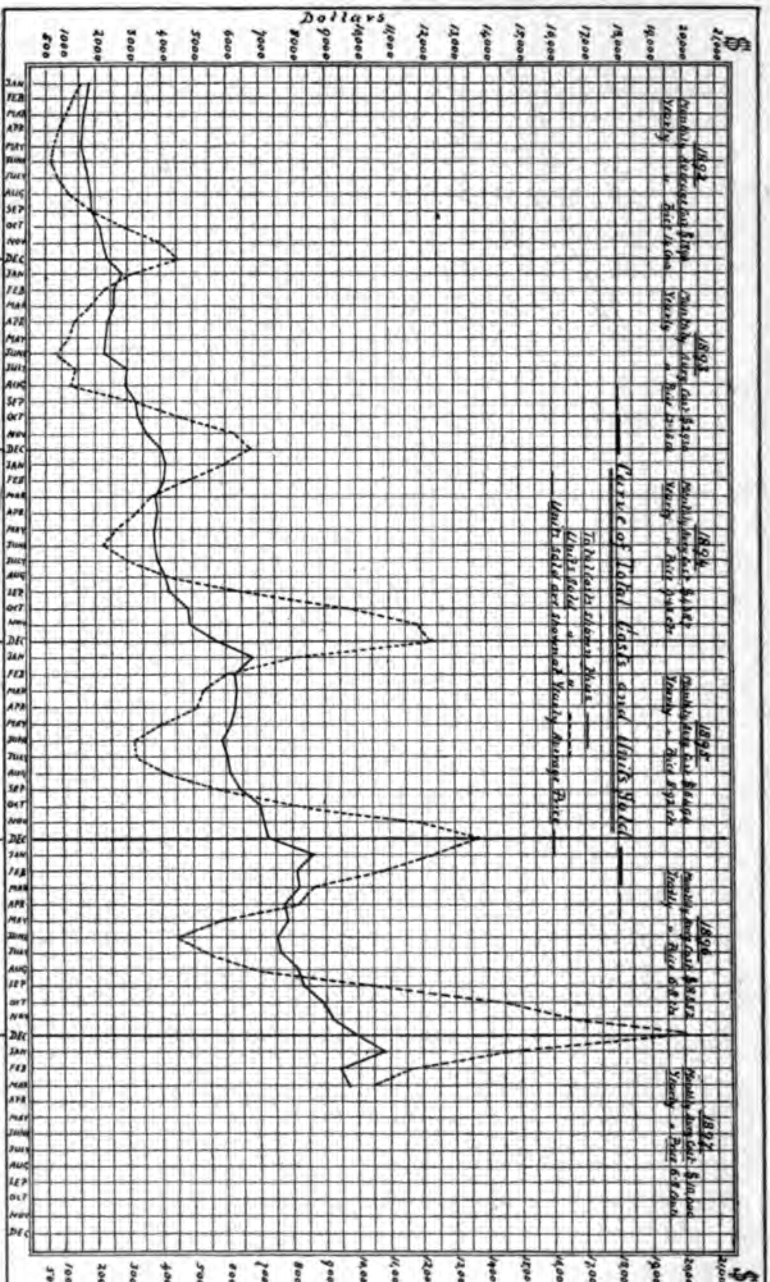
other town in the United Kingdom; viz., seventeen kilowatt hours consumed per inhabitant this year. The columns of the tables have been arranged in a form which will enable company managers to compare their results with the figures given.

The first small station was built on the usual pioneering lines adopted by many companies before security of franchise could be sufficiently assured to tempt capitalists to put much money in the concern, and the second on the modern lines of a permanent station possessing an absolutely secure franchise. As both concerns, in their respective years, were quite free from any promoter's paper capital, and always gave a supply whenever and wherever called upon to do so, the author sees no reason why the figures given should not form a basis for estimating the cost of supplying electricity under the most diverse conditions, by the necessary alterations being made in the cost of capital, coal, etc., and thereby enable any manager to find out the proper basis upon which to construct an equitable tariff for any particular town or condition of supply.

Columns have been inserted in the tables giving equitable charges that should have been made to the consumers during the different years on the two systems of charging advocated by the author, the first being based on the principle of charging the amount shown in Column 9, of Table I, per annum per maximum kilowatt demanded by each individual consumer, and then charging all the electricity consumed, quite irrespective of the purpose for which it has been used, at the rates given in Column 10 of the same table; and the other tariff, which is commonly known as the Brighton system, of charging a sufficiently high price per kilowatt hour consumed,



Curve showing Varying rate of current Charges
on the Brighton system owing to the development
of the business.
Varying Cost per K.W. hour in cents.
Average number of hours Maximum Demand is used per day throughout the Year.
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
1887
1888
1892
1893
1894
1895
1896


Curve of Total Costs and Units Sold
Dollars
1892.
1893.
1894.
1895.
1896.
1897.
Dollars.

until all the costs the company are put to in standing by have been covered; these figures being given in Columns 11, 12 and 13, respectively, of same table. The fact of this system having been adopted in about thirty English towns will convince the members of its commercial practicability.

On this tariff it is advisable to make the difference between the initial price and the reduced price as marked as possible.

In the preparation of the tables, the author has employed the method of *cost analysis by differences*, explained at length in his paper before the London convention of the Municipal Electrical Association in 1896. In arriving at the total charges against the revenue accounts for the respective years, he has assumed that all stockholders would be quite willing to invest their money if five and one-half per cent on it were put aside out of revenue for the purposes of redemption and depreciation, and at the same time there was a reasonable chance of their getting another five per cent, at least, for the use of their money. He regards this as sufficiently liberal, as, so far as his knowledge goes, very few electricity companies set aside so large a percentage as five and one-half per cent on the whole of the capital for depreciation and repayment of capital, exclusive of dividends. With this provision the author has prepared the columns already referred to, showing what the tariff should have been to have produced this satisfactory result.

In a perfectly equitable system of charging, which, in the author's opinion, will generally be found synonymous with the soundest commercial tariff, it is obviously correct to make every one, whether using electricity for power or lighting purposes, pay

the cost the company is put to in preparing the plant to supply the individual consumer's demand. Column 9, on Table I, is therefore given, showing the cost of so doing during the various years, and it is obviously inadvisable to look for a profit on this expenditure, or on the service rentals, but to make the whole of the net profit for dividend-paying purposes on the amount of the electricity actually consumed.

It must be understood that these tables have been prepared without making any arbitrary assumptions, and that the various amounts for running, standing-by, and service rentals have been ascertained by the aforesaid method of differences and by a close analysis of the stations' costs sheets.

It will be seen from Column 5, Table III, that, at Brighton, where coal on the average costs about $5 a ton, delivered in front of the boilers, the cost of producing the electricity has always been very small compared with the cost of getting everything ready to supply.

The author need hardly remind company managers that where coal is relatively cheaper, or water power is the source of energy, this proportionately large amount of standing-by costs will be still further increased.

It may be thought that all this great cost of putting the station in a position to run, compared with the cost of actually running the machinery, will practically disappear with a large extension of the motor supply business. This, in the author's opinion, is a complete fallacy, as the lighting load in any town will be very similar, however general the supply may become, and whether a constant day load is added to this or not makes no difference at all in the relative

TABLE I.—Showing development of business, proper charges for service rentals, standing-by, and for current consumption.

| Type of station. | System. | Date. | Year of operation. | Annual sales of electricity. In K. W. hours. | Annual sales of electricity. In 50-watt lamp hours. | No. of house services at end of year. | Correct annual charge per service. | Correct annual charge for standing-by per consumers' maximum demand in K. W. | Correct charge per K. W. hour to pay cost of running and to produce additional 5% on investment. | Inclusive charge per K. W. hour consumed on the average in one hour per day throughout the year. | Inclusive charge for supplying one 50-watt lamp one hour daily on average throughout the year. | Subsequent charge per lamp hour (including renewals). | Ratio of charge for first lamp hour to subsequent lamp hours (exclusive of lamp renewals). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| | | | | | | | $ | $ | cents. | cents. | cents. | cents. | times. |
| PIONEER... | Overhead wires, multiple series, H. T. continuous ... | 1887 | 2 | 53,000 | 1,060,000 | 57 | 23.40 | 214 | 8.58 | 67.08 | 3.394 | .469 | 7.8 |
| Do. | H. T. alternating, house transformer system ....... | 1888 | 3 | 75,000 | 1,500,000 | 86 | 14.86 | 170 | 8.8 | 55.3 | 2.805 | .48 | 6.3 |
| PERMANENT | Buried conductors two-wire L. T. storage battery, 1,500 amp.-hrs. capacity. ....... | 1892 | 1 | 156,041 | 3,120,820 | 212 | 14 | 82.1 | 9.775 | 32.27 | 1.664 | .539 | 3 3 |
| Do. | Ditto, three-wire L. T. sliding scale ........... ...... | 1893 | 2 | 286,895 | 5,737,900 | 420 | 10.26 | 69.5 | 7.17 | 26.22 | 1.3505 | .398 | 3.65 |
| Do. | Ditto, with H. T. alternating sub-stations and L. T. distributors .................. | 1894 | 3 | 583,701 | 11,674,020 | 853 | 7.28 | 46 | 5.9 | 25.55 | .9675 | .335 | 4.34 |
| Do. | Ditto.......... .......... | 1895 | 4 | 867,494 | 17,349,880 | 1,065 | 8.60 | 49.8 | 5.28 | 18.93 | .9865 | .304 | 3 58 |
| Do. | Ditto....... ............ | 1896 | 5 | 1,388,821 | 27,776,420 | 1,366 | 7.68 | 50.4 | 4.06 | 17.86 | .933 | .243 | 4.4 |

TABLE II.—Comparative effects of the correct charges during the various years of development.

| Date. | Year of operation. | Inclusive daily charge per K. W. hour consumed in one hour. | Inclusive daily charge per K. W. hour consumed in four hours. | Ratio charges bear per K. W. hour if consumed in one hour and four hours respectively. | Ratio of charge for first lamp hour to subsequent lamp hours (including lamp renewals). | Inclusive charge for supplying one 50-watt lamp one hour daily on average throughout he year | Inclusive total charge for supplying one lamp for *four* hours daily (including lamp renewals). | Inclusive total charge for supplying one lamp for *ten* hours daily (including lamp renewals). | Equivalent cost of gas giving same C. P. with ordinary burners per 1,000 feet, according as the lamps are burned. 1 hour daily. | 4 hours daily. | 10 hours daily. | Annual cost of current for 500-watt arc lamp burning ten hours daily. | Inclusive annual cost of 500-watt arc lamp, with attendance and carbons, but exclusive of interest on lamp and post. | Correct charges for motors of 75% efficiency. Annual charge per maximum B. H. P. | Cost of current per K W. hour. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| | | cents. | cents. | | | cents. | cents. | cents. | $ | $ | $ | $ | $ | $ | cents. |
| 1887 | 2 | 67.08 | 23.23 | 2.89 | 7.2 | 3.394 | 4.8 | 7.615 | 4.24 | 1.5 | .95 | 264 | 307 | 214 | 8.6 |
| 1888 | 3 | 55.3 | 20.45 | 2.71 | 5.83 | 2.805 | 4.245 | 7.125 | 3.5 | 1.325 | .89 | 245 | 286 | 170 | 9 |
| 1892 | 1 | 32.27 | 15.4 | 2.10 | 3.1 | 1.664 | 3.28 | 6.515 | 2.08 | 1.025 | .813 | 219 | 262 | 82 | 9.7 |
| 1893 | 2 | 26.22 | 11.93 | 2.2 | 3.38 | 1.3505 | 2.5425 | 4.9325 | 1.67 | .792 | .615 | 165 | 208 | 69 | 7.17 |
| 1894 | 3 | 25.55 | 9.06 | 2.82 | 2.87 | .9675 | 1.9725 | 3.9825 | 1.21 | .613 | .498 | 131 | 174 | 46 | 6 |
| 1895 | 4 | 18.93 | 8.7 | 2.18 | 3.25 | .9865 | 1.8975 | 3.7225 | 1.235 | .59 | .465 | 121 | 164 | 50 | 5.28 |
| 1896 | 5 | 17.86 | 7.51 | 2.37 | 3.85 | .933 | 1.6200 | 3.12 | 1.165 | .505 | .39 | 100 | 143 | 50 | 4 |

# TABLE III.—Data for determining the correct charges.

| Date. | Year of operation. | Total annual standing-by charges per maximum K. W. at station. | Running costs per K. W. hour. Coal. | Stores and water. | Half repairs to machinery and plant. | Total | Amount of profit to equal 5% additional interest on capital invested. | Daily cost per 50-watt lamp of standing-by. | Correct charge per lamp hour for continuing to supply (including lamp renewals). |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | $ | cents | cents. | cents. | cents | $ | cents. | cents. |
| 1887 | 2 | 214 | 3 | 1.8 | .48 | 5.3 | 1.735 | 2.925 | .469 |
| 1888 | 3 | 189 | 3.3 | 1.32 | 68 | 5.3 | 2.615 | 2.325 | .48 |
| 1892 | 1 | 103 | 2.42 | .06 | .0368 | 2.546 | 11.265 | 1.125 | .539 |
| 1893 | 2 | 94.25 | 1.416 | .214 | .0302 | 1.66 | 15.775 | .9525 | .398 |
| 1894 | 3 | 70.80 | 1.32 | .324 | .176 | 1.82 | 23.700 | .6325 | .335 |
| 1895 | 4 | 75.60 | 1.27 | .162 | .104 | 1.54 | 32.500 | .6825 | .304 |
| 1896 | 5 | 73.79 | 1.016 | .118 | .077 | 1.21 | 39.125 | .690 | .243 |

TABLE IV.—Showing total investment and annual charges to revenue account.

| Date. | Year of operation. | Capital sunk in undertaking at end of year. 1 | Capital sunk in mains and services, exclusive of meters, etc. 2 | Plant investment. 3 | Total charges to revenue account, including service costs, and 5½% on capital. 4 | Total annual service cost. 5 | Total running costs for K. W. hours sold. 6 | Ratio of standing-by charges to actual running costs of year. 7 | Cost per mile of street for mains and services. 8 | Cost of mains per service connected. 9 | Plant investment per service. 10 | Plant investment per K. W. of maximum demand on station. 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $ | $ | $ | $ | $ | $ | | $ | $ | $ | $ |
| 1887 | 2 | 44,800 | ..... | ...... | 12,720 | 936 | 2,810 | 3.19 | ..... | ... | ... | ... |
| 1888 | 3 | 59,750 | ...... | ...... | 18,830 | 1,070 | 3,980 | 3.46 | ...... | ... | ... | ... |
| 1892 | 1 | 255,000 | 101,000 | 72,300 | 22,450 | 2,060 | 3,975 | 4.16 | 23,700 | 480 | 341 | 452 |
| 1893 | 2 | 375,000 | 175,500 | 89,400 | 35,000 | 3,240 | 4,765 | 5.67 | 19,500 | 419 | 213 | 312 |
| 1894 | 3 | 574,000 | 266,000 | 132,500 | 51,200 | 4,630 | 10,650 | 3.38 | 15,200 | 312 | 155 | 262 |
| 1895 | 4 | 728,000 | 326,500 | 165,200 | 78,250 | 8,250 | 13,330 | 4.25 | 16,600 | 306 | 155 | 210 |
| 1896 | 5 | 857,500 | 384,000 | 194,000 | 99,000 | 9,350 | 16,800 | 4.34 | 17,500 | 281 | 142 | 196 |

TABLE V.—Showing lamps connected, maximum load, diversity factor, and length of distributing mains.

| Date. | Year of operation. | Equivalent No. of 16-C.-P. lamps connected at end of year as applied for. | Diversity factor of the consumers as a whole. | Mean of the two-years' station maximum loads in K. watts. | K. W. hours sold in the year per mean maximum K. watts. | Length of streets with distributing mains at end of year. |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | | | | | | miles. |
| 1887 | 2 | 5,614 | 1 | 42 | 1,260 | .... |
| 1888 | 3 | 8,880 | 1.11 | 73 | 1,025 | .... |
| 1892 | 1 | 5,614 | 1.25 | 160 | 913 | 4.25 |
| 1893 | 2 | 9,880 | 1.36 | 287 | 1,000 | 9.5 |
| 1894 | 3 | 19,243 | 1.54 | 508 | 1,150 | 17.5 |
| 1895 | 4 | 25,032 | 1.54 | 740 | 1,170 | 19.75 |
| 1896 | 5 | 33,319 | 1.46 | 990 | 1,405 | 22.05 |

cost of supplying lamps one hour or, say, four hours. Until storage batteries become much cheaper than steam generating plants, the ratio of the standing costs to the running cost for lighting purposes will remain high.

As the standing charges of late years at Brighton have been found to rise nearly in proportion to the maximum annual load on the station, the author, in estimating the cost of supplying any consumer, debits him with an amount of the standing charges in proportion to his maximum call for current.

The author calls the members' particular attention to Column 4, Table V, showing the enormous increase in the sales per maximum kilowatt load on the station that has occurred since the sliding scale of charging was adopted, at the beginning of the year 1893. From the column it will be noticed that this prolongation of the use of the plant has been no less than fifty-four per cent in four years, and it is perhaps needless for the author to point out what a great effect this has had in reducing the cost of production, as, with coal costing even the high price it does at Brighton, an improvement of the load factor of only three per cent has the same effect in reducing the total cost of producing electricity as if the coal bill had been reduced fifteen per cent.

It will be noticed from the tables that the only items that were found to vary with the amount of electricity actually sold from a given plant, were coal stores, water and repairs. Should any managers find that their wages or other costs vary also on this account, it is easy to separate these into standing-by and running costs by the above simple method of differences. Perhaps it may be well to remind those members who did not read the author's paper on the

"Cost of Electricity Supply", in England, last year, that this method of analysis by differences is a means for determining the cost the station is put to in having to supply every additional kilowatt hour from its plant, and it consists in dividing the difference between the amounts debited in the six winter and six summer months, respectively, to the special account required to be so analyzed by the difference in the number of kilowatt hours sold in these two respective periods, the result giving a very correct estimate of the running cost per kilowatt hour during that year.

In the comparison of the cost of an electric lamp with that of gas, it has been assumed that the gas is of a quality known as sixteen candles, which, burnt with ordinary burners, generally gives two candle-power per cubic foot.

In order to make the comparison, in Columns 8, 9, 10, of Table II, between the charges for electricity and gas, applicable to other towns, it seems to the author fair to assume that the ratio of the cost of producing gas and electricity in any one town bears generally a constant ratio, as the items which affect this, such as the cost of capital, coal, labor, etc., would generally vary in similar proportions.

From Table II it will be seen that, even in the year 1893, when something under 300,000 kilowatt hours were sold, the charges for a sixteen-candle-power lamp, burning four hours a day throughout the year, would have been less than gas at eighty cents per 1,000 feet, and that last year, when the supply was under 1,500,000 kilowatt hours, electricity burnt under these circumstances could compete with gas at fifty cents; while for street lamps, or lamps used in basements all day long, electricity was cheaper than gas at $1 per

1,000 feet, in 1887, supplied from the small pioneering station.

Columns 11 and 12, of Table II, giving the charges for current and total inclusive cost for a 500-watt arc lamp, may be of interest, as also may be the proper tariff for motive power, shown in Columns 13 and 14 of the same table.

To illustrate how impossible it is for electricity to be supplied on a uniform tariff at so low a price to the lamps used in the average house of the middle classes as it can be profitably done on an equitable sliding scale, it is only necessary to note that to have produced the same amount of profit in 1896 the uniform charge per kilowatt hour would have been, to this four-hour class of consumer, 9.3 cents against the equivalent charge of 7.5 cents, or at an increased charge of twenty-five per cent.

If we take the case of saloons and clubs, which keep open late throughout the year, and burn, on the average, their lamps six hours a day, the necessary uniform charge would have been forty-six per cent higher, and, in the case of basement users, using their lamps ten hours a day, on the average, throughout the year, a uniform charge would have to have been seventy per cent dearer than it could have been supplied on the system of equal profits, whereas the one-hour consumer, on the uniform system, would have been charged 9.3 cents against the proper charge of 17.86 cents per kilowatt hour, and, as fifteen cents would have been the actual cost to the supply station in giving him this kilowatt hour, the company would have lost no less than six cents for every kilowatt hour so sold.

It may be thought that the amount of the service rentals shown in Column 8, of Table I, to be equitable

in the different years, may prevent the classes the author so strongly suggests should be catered for from being able to benefit in point of economy by a supply ; but it is easy to show from the tables that even in the year 1894, with a sale of 583,701 kilowatt hours in any ordinary residence where at least four lamps are generally used till 10 p. m., any householder should have been able to get electricity cheaper than gas. Moreover, directly cheaper forms of electricity meters are put on the market, and meter readings can be taken once a quarter instead of once a month, as hitherto, these service rentals will very much diminish.

In case any of the members should be inclined to think that there is no necessity to depart from the ordinary method of charging a uniform price per lamp hour, the author has prepared the curves showing how very slightly the total costs of a central supply company vary in the different months of the year, notwithstanding the enormous variation in the number of kilowatt hours sold. These curves, in the author's opinion, are the most speaking condemnation any manager can possibly have of the commercial unsoundness of the uniform method of charging.

In order to demonstrate very clearly the effect of the gradual development of the business on an equitable sliding scale of charges, the author has prepared the curves showing how the varying charge per kilowatt hour, according to the number of hours the demand is used, has diminished in the various years, as many managers have suggested that this necessity for a high initial rate will disappear on electricity being more generally used.

DISCUSSION

The President: Before calling for discussion of this paper, I might explain that Mr. Wright has left out a good deal of the paper in reading it, owing to the fact that it has been in the hands of all our active members for some time, and in order to allow more ample time for discussion. I now call for a discussion of Mr. Wright's paper.

A Member: I should like to ask Mr. Wright what his machinery is; whether it is in large units connected, or whether it is in small units. I presume that he runs by steam condensing. Of course, we do not know his conditions, and it might be interesting to learn a little more of them.

Mr. Wright: I would answer the gentleman by saying that the whole of the plant is direct-connected, and, in the years analyzed, there was no condensing plant.

Mr. Bean: I should like to ask Mr. Wright what is his longest transmission line?

Mr. Wright: Two miles from the station.

Mr. Ferguson: I should like to ask Mr. Wright what the lease price is for a kilowatt hour.

Mr. Wright: Fourteen cents.

Mr. Ferguson: The price for extra hours?

Mr. Wright: Three cents.

Mr. Ferguson: Is it an additional three cents per hour for every additional hour?

Mr. Wright: Yes, sir.

Mr. Ferguson: What is your average income?

Mr. Wright: The average income per kilowatt hour—this year it will be six cents.

Mr. Ferguson: Then, I should like to ask, Mr. Wright, what the cost is? I didn't quite gather that from the tables.

MR. WRIGHT: You mean in the year 1893? What year, sir?

MR. FERGUSON: Last year.

MR. WRIGHT: It is not given here. The actual cost came under eight cents. This year (I answered that about six cents is the average revenue) it is very much less. The tables refer to last year, and my first answer referred to this year.

MR. INSULL: Do I understand that the plant was run at a loss last year?

MR. WRIGHT: No, sir.

MR. INSULL: The cost was eight cents?

MR. WRIGHT: Yes.

MR. INSULL: Per kilowatt hour?

MR. WRIGHT: Yes.

MR. INSULL: And the selling price?

MR. WRIGHT: Last year we derived about nine and one-half cents.

MR. BEGGS: I should like to ask what the selling price of gas is? I do not know whether that is stated in the paper or not.

MR. WRIGHT: Sixty-six cents per thousand.

MR. BEGGS: And on your most favored customer you are discounting gas fifty per cent? Is that the fact?

MR. WRIGHT: Four-hour or ten-hour customer?

MR. BEGGS: Your most favored customer. If you are selling electricity at three cents per kilowatt hour, you are selling upon the basis of gas at thirty cents per thousand cubic feet.

MR. WRIGHT: You have forgotten the first hour being charged at fourteen cents.

MR. BEGGS: I am not asking about the first hour; I am asking what your most favored customer would get on his average cost?

MR. WRIGHT: It all depends on the number of hours he uses it?

MR. BEGGS: For instance—I am asking you now to take your most favored customer—the customer that gets from you the lowest rate that you give from your station; what is his rate per kilowatt hour on his entire consumption?

MR. WRIGHT: It is on the table; three and one-half cents is the average.

MR. BEGGS: Then, in other words, I simply claim that, in my opinion, you are doing a very great injustice, and one that would have aroused such a warfare in this country as would have antagonized many interests that we have found it desirable really to work in harmony with. In other words, you are cutting the price of gas in half to your most favored customer, and, in my opinion, it is a very great injustice to your customers whom you are making pay a very much higher rate in order to pay for this extremely low rate that you are making to your most favored customers. We have not yet gone quite so far as that in this country, even on our basis of charging more than uniform rates, and without this great amount of detail to arrive at it and some sketch by which a customer can know what his bills will be. I simply wanted to draw out the fact of how greatly you were undercutting the price of gas. In this country, a certain gentleman on this floor knows that I have for several years taken the position that we must ultimately compete with gas. I have never felt that we ought to cut under gas. My whole policy for the last fourteen years that I have been managing electric lighting plants has been to bring down the price of my commodity to the price of gas; and I do not to-day give any customer on

the lines of the companies that I supply electric light for, less than the basis of gas. I claim that we do not need to depreciate its value; but I do believe that the time has come when, to hold and increase our business, we must put our commodity upon the same basis as that on which gas and water are sold, and we are trying to do that. For instance, my lowest rate for electric current is ten cents per thousand watts. That is upon the basis of gas at one dollar per thousand cubic feet. Now, I do not think that it is necessary to go below that in order to compete with gas. But, gentlemen, there is another factor that we are all called upon to compete with, and that is our own friends, the installers of isolated plants. They are the greatest menace to our central stations to-day. They are the people that I fear far more than the gas companies; because I do not fear any gas company in the United States to-day. I told one of the most prominent gas men in this country, possibly (a man who has antagonized and fought the electric lighting interests with more intelligence than any man I know), three years ago, when I went into a hostile community to see if it was possible to sell some electric current there, that I could compete with his gas at fifty cents per thousand feet and lose less money than he lost when he attempted to follow the price. It had a very wholesome effect, I tell you, gentlemen. And while he thought I was a fool, at that time, or a crank, or an enthusiast, as he said, upon the subject of electric lighting, I think his opinion has very radically changed in the three years. But what we are called upon to compete with to-day, and what I think this association is having a restraining effect upon, are the brethren throughout the land who are installing

isolated lighting plants, by which they can show the owner of a large building—and I am going through one such experience at the present time; am called upon nearly every week to do so—where he can prove to the owner of a large building that he can install a plant, that he can run it twelve months without cost, and, at the end of the year, can declare a dividend to himself. And there are those here that are in charge of these manufacturing companies who won't employ an agent unless he can demonstrate that. I speak advisedly, because I used to have some of them in my employ. But, gentlemen, I believe in a uniform rate that is not so complicated as Mr. Wright's methods. I have made a uniform rate, and I am trying to make it as simple as possible. I am gradually getting down to a basis, and I believe that the more intelligent central station managers throughout the country—and not only charged with the management, but the larger central stations in this country to-day are those that are in the hands of people who have large investments in the properties they are managing—they are called upon, not only to count the coal pile and the gallons of water, but they have millions of capital for which they are responsible, and they must look upon the returns for that. It is the amount of your bank balance at the end of the year with which you pay your dividends and profit and depreciation-reconstruction reserve. There is one factor that has been largely overlooked in the years gone by. In the companies with which I am connected, I have opened an account, whose technical ledger title is "Depreciation-Reconstruction Reserve," to which a certain amount of money is carried monthly, and carried as a liability of the company, and the funds kept in hand for use in the years to come, when either our

present installations may become antique, or some unforeseen circumstance arise whereby we could not have the means to put ourselves in position to compete with the advances made in either the production of gas or more modern electric lighting plants. And that is the strongest assurance we can have. I may say, in a general way, that I make a scale and I publish it. My schedule of rates and discounts is published on the back of every bill that goes to every customer in my companies. I throw out the challenge that if any customer can find a cut in that rate he may publish it as my standard rate. I am well aware that that cannot always be done to start in with. For instance, I have my bill here in my pocket—these things have to be considered in view of the local conditions—I start in with a bill of five or ten dollars, giving a certain discount that brings it down; but when the customer is using fifty dollars' worth monthly, the price of that current is exactly what he would have paid for any number of candle power of gas equal to mine. In other words, it equals one dollar per thousand cubic feet. I have tried to get my stations in such position that if the gas companies cut to fifty cents per thousand cubic feet I can follow, and still be prepared to make some money. This is the point I wish to bring out in this suggestion regarding Mr. Wright's paper. He shows you that it is profitable to sell electric current at three and one-half cents per kilowatt hour, or thirty-five cents per thousand cubic feet of gas. That is the rate.

Mr. Insull: Mr. President, Mr. Wright and gentlemen, I do not think that the question Mr. Wright has brought up for our discussion is one as to whether or not it is good policy for us to compete with gas. I do not think that is the question with

which we have to deal under this paper. He has brought before us the question as to whether we should get a return on our investments from every customer that we may connect to our circuits; and he has drawn our attention to the fact that if you will figure fixed charges and dividends and administrative expenses, you will have got the highest item of cost per kilowatt hour; in fact, from five to ten times as big as any other item that you can get on your cost sheet. I am running a company that is applying the Wright Demand system in practice, but not in theory; and, as Mr. Wright has been kind enough to give us credit on this side for the first development of central station lighting, I should like to bear witness here to the fact that the policy adopted by the company that I am running was adopted partly on the reading of one of Mr. Wright's papers by my general superintendent, Mr. Ferguson, and partly as a result of a conversation that I had with Mr. Wright when going from Thames Ditton to London some three years ago. As Mr. Beggs pointed out, we have to compete with the isolated plant. That part of his remarks I especially wish to emphasize here, and I assure you, gentlemen, that if you are going to assume that the lowest price that you can charge for electric current is the price that is at present charged for a unit of light by the gas companies of this country, you cannot compete with incandescent isolated plants. I can show you cases where you have got to go as low as six, or four, or four and one-half, cents per kilowatt hour, if you are going to compete with the isolated plant; and if you expect your business, not in the large cities only, but in the smaller cities, to assume anything of the proportions of the gas business as a lighting enterprise,

you have got to face the difficulty of competition with isolated plants; and whether you adopt one method or another,—whether you adopt the meter, which is practically the result of Mr. Wright's advocacy of his variation of charges, and charge a fixed rate for a given period, and a much lower rate for a longer period, or whether you figure out the amount of time each customer uses your investment per day—you get around finally to practically the same results. I can show you two buildings, practically alike, not the length of this room apart. In one building the average consumption of light is 200 hours a year, and in the building on the other side of the street, the average consumption is 2,000 hours a year. Now, is it fair that when you have to provide precisely the same investment for the man that uses your investment 200 hours a year, you should charge him on the same basis as the man that uses your investment 2,000 hours a year? And that is the basis of the proposition laid down here by Mr. Wright. It is a question of getting a return on investment; getting a correct share of your dividends, if you are fortunate enough to pay them, from every customer; getting from every customer a correct share of your administrative and other general expenses. I care not, in figuring my price list,—whether it is a published list or a confidential list, whichever may be the best to use, changing with the local conditions—I care not whether I am competing with gas or tallow dips. I am running my company to satisfy my stockholders, and I can only satisfy my stockholders by giving them a return.

A short time ago I was foolish enough to go into print; I usually avoid it. I made the statement that there were some of our companies in this country selling as low as six cents per kilowatt

hour. My friends of the gas company in Chicago drew my attention to that statement, and said that meant sixty-cent gas. They had told me a few months before that it didn't mean sixty-cent gas, because there was so much difference between a sixteen-candle-power lamp and a five-foot gas burner. But I admitted it; I said, "Yes, it means sixty-cent gas." But what are the facts? I suppose some of you must have been in Chicago at one time or another, and know that we have in the centre of the town a lot of very big department stores. Unless I was willing to do business on the basis of six cents a kilowatt hour, I might just as well take up our conductors and get out of the territory where those department stores are. What do we find? The people who run those stores, owing to the changed conditions and the character of illuminant that they can use, find that they can use an illuminant that does not give a great deal of heat; they can light up their windows; they put goods in the front of those windows, and they depend all day upon artificial light. Would this be possible if they had only gas to depend upon for artificial illumination in those stores? Why, it would get so hot that they would have to get out of them; they would get no customers in their stores. But with arc or incandescent light the condition is entirely different. And what is the result? Our investment in lighting plant is in use a great many more hours a day, owing to the fact that they can use an illuminant that enables them to run their business with artificial illumination. Would you expect that the man that burns his light ten hours a day, 3,000 hours a year, should pay the same rate per unit as the man that burns it 200 hours a year? Mr. Beggs, in reply to that, would say that his basis of discounts gets over

the difficulty; but that is not so. We have one building where if our bills were rendered against the owner of the building instead of the tenants, they would be entitled to our biggest discount. It is the largest building in Chicago, and yet, as a matter of fact, it is not very profitable business at twenty cents per kilowatt hour; whereas a man that has a comparatively small store, on State street, and who pays just about the same amount per annum,—why, his business is ever so much more profitable at seventy per cent off twenty cents a kilowatt hour, or six cents a kilowatt hour. I rise to indorse the scheme Mr. Wright has in view; that is, the result he wants to achieve. I tell you, gentlemen, it has more to do with making our small plants successful, and saving the appearance in some of our papers before this association of the statement that the only profitable business is the city contract, than anything else you can discuss at this convention.

MR. STETSON: Mr. President, I congratulate the author of this paper upon the manner in which he has presented this important contribution, and the fact of its discussion by the two gentlemen who are probably better able to present their different sides of the question than any other two men in the United States. I believe my friend on the right (Mr. Beggs) would be a little lonesome if he tried to compete with gas where three feet of gas at less than one dollar per thousand furnishes some fifty to seventy-five candle power light. That is done in the Welsbach burner. And if my friend on the left (Mr. Insull) had not fully illustrated that the position that the electric light occupies is one that is entirely impossible for gas light in the case of large installations, where the heat would be such as to make it prohibitive, an important ele-

ment of the discussion of the subject would certainly have been omitted. We do not want to fight the light question on the ground of competition with gas; I do not believe in that. You have two commodities that have to be used in different relationships entirely. And I do not believe that this paper is entirely correct in its principle and its application. I believe that one lesson that should be learned is that our patrons should be educated to understand that there is money, that our plant represents money that is lying there every minute of the time, and that it absorbs value, and you have to get from that value some return. If a person only wants his light for a temporary convenience, it is not right that he should have the absorption of that capital at the same rate as one that burns our light constantly. I am thoroughly in sympathy with the general trend of this paper, and I think that we ought to express our gratitude that it has been so thoroughly elucidated. I believe that it outlines a new course to be struck out in the future in this country, and one that will be successful in saving a great many of the smaller installations that, very unfortunately, do depend on municipal lighting for their business; and if there were a more just and equitable distribution of the cost, it would be quite possible not to lie awake nights to think about the matter so much. I am thoroughly thankful for the discussion on either side, and for the paper primarily.

Mr. Ferguson: Mr. Wright says he charges on the basis of the load factor—on the basis of average load and maximum load—but he makes no distinction in regard to the time of day in which that maximum load comes. In other words, he charges the same rate to a customer who has his maximum load at five o'clock in the afternoon, which is the time of the

maximum load at the station, that he does to a customer who has his maximum load at three o'clock in the morning, when the central station has very little load at all. I think Mr. Wright could go a step farther in his work, and make a difference depending on the time of day at which the maximum load comes; because the interest charges for the man that has his maximum load at three o'clock in the morning are practically nothing, because he uses machinery that would otherwise stand idle; whereas the man that has his maximum load at five o'clock in the afternoon requires additional machinery, and therefore his interest charges would be greater. That would be piled on top of the whole interest charge of the station. Therefore, I think the man that uses the maximum load at five o'clock in the afternoon ought to pay a higher rate than the man that has his maximum load at three o'clock in the morning.

MR. WRIGHT: The question of what time of day you charge your consumer for the interest and other standing charges of the plant that is required to supply him—my answer to that is that all these standing charges are not hourly, monthly or daily charges. They are an entire charge against the whole investment, and if you have an installation taking current up to six o'clock, and another equal installation taking current after six o'clock, both these installations ought to pay half of the necessary investment charges, and not one. I do not see why you should charge the night user the whole of the standing charges. You surely ought to divide the standing charges between the two. Why should you charge the man who uses it after six o'clock and not the man who uses it before six? To answer your question, you must take individual cases. I cannot imagine a better answer

than to imagine two equal plants using the light at different hours of the day. You must charge each its fair proportion of the total investment, and if they are equal installations you must charge them equally half the cost. Divide the cost of your plant between the two. It is unfair to charge one more. Why not charge them both equally?

DR. FENNER: Mr. President, I have been very much interested in Mr. Wright's paper and also in the subsequent discussion. I had not the opportunity to read Mr. Wright's paper carefully, and, as he omitted a good deal of it, I presume there is in it what I failed to catch. But it seems to me that his paper is rather one on the theory of operation than on actual practice; and I believe that if he would give us a five minutes' talk, and tell us how he goes to work practically to charge in Brighton, it would be very interesting to all of us. Now, for instance, I am just entering the business; I run a street railway from Dunkirk to Fredonia. We have installed an electric light plant; we did so about three years ago. Gas was selling there for $2.50 a thousand. We began at $1.50, the equivalent of that, for electric light. The gas company dropped their price to one dollar. We dropped to one dollar. Both plants have been run at a loss for two years and a half. We have lost about fifty dollars a month, and the gas company has lost about $1,000 a year. Now that is finally at an end; I bought the gas plant the other day.

THE PRESIDENT: Is that charged to depreciation, Doctor?

DR. FENNER: It will have to be, I guess. Now, practically, I am going to work to make the charges satisfactory.

JUDGE ARMSTRONG: Satisfactory to whom?

Dr. Fenner: That is, to make some money. And another problem is not to offend the citizens, who have a great liking for cheap gas and a great disdain for cheap electric lights. Of course, we had a poor gas until we put in the electric light, and then it became good. And the Welsbach burner came in at that time; everything seemed to conspire to keep back the electric light plant. Now we have got so we don't care. But continuing Mr. Wright's discourse here, which is the theory of charges, I should not know how to go about it practically until I studied his paper more, and I thought perhaps he could elucidate it further here. Here is a store, for instance, that has been paying the gas company $100 a year, and they have been metering it at 100,000. Now they would like to have a couple of arc lamps and fifteen incandescent lamps, and would run until ten o'clock at night. Then they would run in the morning, and if it was cloudy weather they would run all day. Well, how to go to work to rate them on electric light is the question with me. Here is a private house that has been paying about twenty-five dollars a year for gas; they would like to have electric lights run to them, converter bought and meter bought; and what rate could be made? I see you do not say much about metering; I had supposed that the really economical way of doing this was to meter the electric light to them, just as we do gas. I won't take your time any longer, but I thought that Mr. Wright might elucidate his proposition very nicely with a five minutes' talk here.

Mr. Wright: With your permission, Mr. President, I should like to answer the gentleman, because it is obviously necessary to show how we do it in practice. One of the members stated that it was

complicated. There is an instrument put alongside of the ordinary meter; this instrument tells the station manager and the consumer how much per annum he must pay the company to pay off the charges for getting the plant ready. The ordinary meter shows him the total bill. This is what we call the demand indicator. The meter shows the total amount of electricity consumed, and the demand indicator tells him by direct inspection how much of that electricity has to be charged at a high rate, and all the balance at a low rate, in order to make him profitable. The instrument does it without calculation. The ordinary meter reads these two instruments. Say you have 1,000 units; 700 units have to be charged at fourteen cents, and the balance of his bill, as rendered by the ordinary meter, has to be charged at three cents. The instrument does all the calculation. The instrument shows you at once how much revenue you must get from that consumer to pay on your standing charges; and if you get more than that, you charge him at the lower rate of three cents; because, as I show in my paper, which I hope the gentleman will read later on, the cost of continuing to run with coal as we pay at Brighton, after everything is paid for to get ready to run, is only one cent; and we put a certain amount of profit on the one cent to bring up our total profit on the investment to what we call ten and one-half per cent; five and one-half per cent for redemption and five per cent for satisfying the stockholders. The instrument shows you this at once. Mr. Insull stated that it might be possible to do this without an instrument, but I think the cost of doing that would be exceedingly great; because, if you have 6,000 or 7,000 consumers, for instance, you have a sort of justice rule—I can hardly say arbitrary, but

settling each customer's discount as he comes in; whereas the instrument, which is based on absolutely scientific principles, can do the work for you, and a cheap meter reader, in conjunction with this instrument, takes the place of a very highly skilled arbitrator. I hope I have made myself clear.

DR. FENNER: Is that instrument connected with every consumer?

MR. WRIGHT: Every consumer.

DR. FENNER: One end with the consumer and the other end in the central station?

MR. WRIGHT: No; next door to the meter, in the consumer's place. I might illustrate the working of it. Suppose that you have a large consumer, with 1,000 lamps installed. The chances are that never more than 400 or 500, we will say 600, of those lamps are required to be lighted simultaneously. Now, the station is only concerned with those 600 lamps, and not concerned with the remaining 400. The station has to put down mains and plant equivalent to the 600 lamps, and the standing charges are therefore proportioned to the number of lamps actually required to be lighted. And I want to draw the distinction between that and the number of lamps wired. We charge on the number of lamps required to be simultaneously alight, because that governs the amount of plant you have to hold in readiness to supply that consumer. Then we say that that consumer must pay sufficient to pay the interest and other standing charges on that 600-lamp plant. We are not concerned with the one hundred lamps, we are concerned with the 600. If you can find out, as you can in some stores, the exact number of lamps required to be simultaneously lighted, an instrument is not necessary; but when we come to the larger field of

domestic lighting, that becomes impossible; it becomes too complicated.

Dr. Fenner: Do you vary this fourteen-cent charge in accordance with whether it is all done in an hour or whether it is spread over the twenty-four hours?

Mr. Wright: Yes. When we first started it, we charged fourteen cents for two hours per day, or 730 hours per annum. As we got larger, the standing charges diminished in proportion. Then we diminished the time during which it was necessary to insist on the high charge.

Lieutenant Greene: Mr. Wright states that he bases his standing-by charge on the maximum number of lights required to be burning at any one time. How does he arrive at that figure? For instance, in this hotel, 1,000 lights. How do you know how many lights they have at one time, maximum?

Mr. Wright: Measure it by the ammeter—recording ammeter.

Lieutenant Greene: Do you take that for a sufficient length of time to get the maximum? For instance, you say 600 lights; but they might have a convention like this—

Mr. Insull: Always in circuit.

Mr. Wright: Always in circuit. Then we give him the benefit of this winter maximum. Take the maximum in the month of the year in which the peak of your main station occurs, and give him the benefit of the average of those six maxima. We consider that gives a fair—not perfect—idea of the amount of plant required; a fairly good idea of the amount of plant required to supply him.

Mr. Ferguson: I do not like to let that point go by without replying to Mr. Wright's statement.

He thought it was perfectly fair to charge half the amount to each customer. Now, I can show him why that is not fair. Take as an example, for instance, a central station like our own, that has certain customers that use the light through the twenty-four hours; others that go off shortly after six o'clock, and others that use the light—or power—only from twelve until morning. Now, the people that run the newspapers are very important people, and we sometimes have to favor them so as to keep out of print; and the newspapers, a great many of them, use electricity for operating their printing presses, and the newspapers are usually printed after twelve o'clock at night; between twelve and morning. Now, it doesn't seem fair to charge the newspaper that uses the service only from twelve until morning any portion whatsoever of the interest charges when they use the same machinery that is provided for somebody else; so I think my statement, as originally made, is correct. I have given that as an example.

MR. WRIGHT: I think that a very good illustration, sir; I will try to answer it; I hope I may convince Mr. Ferguson. I do not yet understand why the people using current for lighting purposes should be debited with the whole cost of getting that plant ready. I think a certain proportion of that cost should be paid by the printing-press people. The fact that it is not coincident diminishes the amount of plant that you have to put down in your station. Both the lighting and the printing-press consumers are indirectly given the benefit of that non-coincident. You do not have to put down so much plant; your standing charges are not so high. The printing-press man does benefit from the non-coincident, but when we are lighting a man he also has the benefit. The stand-

ing charges are not so high, because of that non-coincidence. Suppose the printing-press man came on the top of the heap. The standing charges to both would be very much higher. The fact of the non-coincidence is taken into account by the smaller standing charges. But we still say, pay fairly; pay for your plant, and do not charge other people for the plant that supplies you.

MR. FERGUSON: Then I take Mr. Wright's answer to my question as simply that he will draw an arbitrary line, and call it fifty per cent to one man and fifty per cent to the other; although I think he perhaps admits that it is simply an arbitrary division, because the interest charges are proportioned arbitrarily to the maximum load at the station.

MR. WRIGHT: That is right; and they have to be divided among your consumers in some, we will say, uncertain way—these standing charges. The question is, ought the printing-press man to pay none of these standing charges? And if it is granted that he should pay some, how much? We say, in the proportion of the ratio his demand bears to the total demand of the station. We divide the total standing charges to him in the same ratio that his demand bears to the total amount of the station. We say that may not be perfectly equitable, but we cannot imagine any more equitable system of doing it that would be commercially practicable. To arbitrarily say, "Now, you use it after twelve o'clock, therefore we will charge you no standing charges," seems to me a little unfair to the lighting man, and you stop him from using the light because of its necessarily higher price.

MR. FERGUSON: The point is that the man that uses the service in the morning,—his service is practically a by-product of the station, and what he

should be charged with would be simply the value to him of the machinery at that time; that is, such a ratio between the kilowatt hour he would use and that the lighting people use during the daytime at the time of the maximum load. But you say that, instead of figuring that out mathematically, you take it fifty per cent to one and fifty per cent to the other.

MR. WRIGHT: If they both use the same plant at different hours of the day, then I say each must pay half. If three people use the same plant at three times in the day, then they must pay one-third each. They must pay equal proportions of the rate at whatever time of the day they use it. This is a very long discussion, Mr. President. I hope to be able to talk privately with Mr. Ferguson, rather than take up the time of the meeting further.

JUDGE ARMSTRONG: I suppose the best possible compliment we could pay Mr. Wright is just what is being paid him here, so far as his paper is concerned. I rise to make a motion—and I want to say, out of fairness to myself, that it is at the suggestion of the chair that I am doing it. Understand, it is his motion, not mine—that we now take a recess until half-past two. The motion for the recess is that this discussion can then be continued, because it seems too valuable to be lost. And we won't take up time in moving a vote of thanks, as we otherwise should, to Mr. Wright; he will understand that he is being thanked in the most practical way possible.

THE PRESIDENT: Before leaving, I have suggested that we do not adjourn, but merely take a recess. It is nearly half-past one now, and the time in which we can get luncheon in the hotel is more or less

circumscribed; and arrangements have been made to have a photograph of the delegates taken on the lawn. Before you leave, I should like you to listen to one or two announcements.

ANNOUNCEMENTS

THE PRESIDENT: I have here a letter just received from Mr. Littell, vice-president and general manager of the Buffalo Railway Company:

"June 8th, 1897.

"Secretary National Electric Light Association,
"Niagara Falls, N. Y.

"DEAR SIR: This company extends an invitation to the members of your association to visit their power house, No. 992 Niagara Street, Buffalo, N. Y. In the power house they will see rotary converters using power from Niagara Falls, and also power generated by the steam plant and used for propelling street cars.

"Yours very truly,
"H. H. LITTELL,
"Vice-President and General Manager."

THE PRESIDENT: I might also state that the long-distance telephone line has been placed gratuitously at the service of delegates at any time between six p. m. and nine a. m.

Any member who has not received an invitation to Mr. Stillwell's lecture, for himself or friends, can procure one or more by applying at the secretary's office.

The railway certificates that have been turned in are now ready for distribution.

We will now take recess until half-past two.

## FOURTH SESSION

The meeting was called to order by President Nicholls at 3 p. m.

### ANNOUNCEMENTS

THE PRESIDENT: Before resuming the discussion of Mr. Wright's paper, I wish to read the following letters:

"NIAGARA FALLS, N. Y., June 9th, 1897.

"MR. GEORGE F. PORTER,
"Secretary National Electric Light Association,
"International Hotel, City.

"DEAR SIR: In behalf of the Buffalo and Niagara Falls Electric Railway, I hereby tender to such of your delegates as may accept the same, an excursion in special cars from this city to Tonawanda and return.

"The trip will occupy but about an hour and a half, and the ride along the river is very pleasant. The excursion will be timed to suit your convenience.

"Trusting that your association will enjoy its stay in this city, I am,

"Yours respectfully,
"W. CARYL ELY,

"President Buffalo and Niagara Falls Electric Railway."

"P. S.—Fur overcoats and lap robes may be left at the hotels, as the cars are electrically heated."

The time appointed for this excursion is such that we shall all have to attend in a body, special cars being provided for our accommodation. The time appointed is five o'clock to-morrow afternoon, and it will get us back in time for dinner at half-past six.

MR. BEAN: Mr. President, I move that the invitation be accepted; that we visit the place in a body, and that we return a vote of thanks to Mr. Ely for the invitation.

The president put the question and it was determined in the affirmative.

THE PRESIDENT: I have also a letter from Mr. Wm. H. Browne, of the Royal Electric Company, Montreal:

"MONTREAL, QUE., June 8th, 1897.

"FREDERIC NICHOLLS, ESQ.,
"President National Electric Light Association,
"Niagara Falls, N. Y.

"DEAR SIR: I regret exceedingly, on my own account, to be obliged to advise you that I am unable to attend the convention, matters that have arisen during my absence at the Canadian Electrical Association demanding all my time here to-day and to-morrow.

"I wish to repeat the suggestion made to you on the train, that in the interest of the electric lighting people they would find it of great value to them to hold their next convention in Montreal, and I should like to have you make the suggestion. I have written also to several other members, who, I presume, will be in attendance, regarding the making of this suggestion.

"Yours truly,

"WM. H. BROWNE."

THE PRESIDENT: As all other invitations have been referred to the executive committee, I presume it is the intention of the association to act likewise in this case. Is it your pleasure that this be referred to the executive committee?

Carried.

DISCUSSION (*Continued.*)

THE PRESIDENT: There was some discussion in relation to Mr. Wright's paper this morning on an instrument described by him that is used in connection with the meter. I will call on Mr. Madgen, of London, England, to give the association some information in this regard.

MR. MADGEN: Mr. Reason will do that, sir.

THE PRESIDENT: Mr. Reason.

MR. REASON: Mr. President, it is now some four years since my friend Mr. Wright came to me and said he could certainly see his way clear in the most simple way to fix a tariff that would be at the same time remunerative to any supply company and equitable to every consumer, provided he could get an instrument that would absolutely fix the actual call made upon his plant by each consumer. Well, Mr. Wright and I worked very patiently in that direction for some time, and it was owing to his suggestion that we finally adopted the instrument that we are now using, which is really a differential gauge adapted with various modifications, so that we really have a thermo-self-recording ammeter, or what we may practically call an ammeter that shows at a glance the maximum demand that the consumers have made upon the station. The index is non-returning. It is liquid. Consequently we lose nothing. The delicacy of the readings is very great, very

accurate. The liquid, of course, naturally lends itself very well in that respect; and, so far as the commercial instrument is concerned, it stands the ordinary rough usage of everyday life. We tried to design an instrument that could be put in a store cellar, that the store boy could play about with without hurting it; and I am quite sure that, so far as the practical use of the instrument is concerned, it will fill the bill.

Now you are good enough to give me a hearing, and I should just like to mention one or two points in connection with my own personal experience with this instrument as being used in other cities besides Brighton. We now have the instrument in use in forty cities in the United Kingdom; and certainly in more than one case it has turned non-profitable companies into dividend-paying companies. I refer more particularly to Northampton, England, and Preston, England. In both those towns the companies had been operating for some three or four years in a most disheartening way. They found they could not make any profit; that year after year the consumers did not consume any more electricity per horse power demanded, because they found electricity dearer than gas. The consequence was that we had in England what we see very largely here, all the short-hour burners given to electric light, and all the long hours, which certainly ought to be on our dynamos, given up to gas. We have now remedied this in the case of several towns in England—I may say in Europe, because we have the instruments in use in other countries besides England. We have been very carefully working to try to reduce the cost of the instruments, in order that when a man may see the wisdom and safety of going in for a tariff that is at the same time protective so far as his interests are

concerned and indulgent to the most profitable of his consumers, it must not be done at a heavy cost; the cost of the instruments must be moderate, and I think I am safe in claiming that, as a recording ammeter, there is nothing that can be obtained so cheaply.

I noted one or two points in the discussion this morning that, with your kind permission, I should like to dwell upon. The question was raised as to whether our experience at Brighton, which Mr. Wright set forth, really yielded a profit at all last year. Now, gentlemen, last year at the central station in Brighton, in addition to the setting aside of a sum equal to five and one-half per cent of the whole capital for depreciation and redemption—which is really a dividend of itself according to the ideas of a great many managers—we, in addition to that, earned nearly six thousand sovereigns, net; that is to say, nearly $30,000, net, on a capital of $200,000, or an extra five per cent over that first five and one-half per cent. That, I think, answers that question clearly. In Brighton we averaged on our tariff something over nine cents per kilowatt hour, right through. Surely we are friends of consumers; and if we made, as we did last year, the profit I have told you about, surely we are the friends of central station managers. Now, there is one thing I have found in my experience in England; that is, that the smaller central stations were very glad to welcome us. The smaller central stations wrote to me, and said: "Come and tell us all about this thing. We are not doing well; help us." I think we have helped them to a certain extent. I know I am very sorry, gentlemen, that I did not follow my own judgment and buy the stock, three years ago, of some of the companies that then adopted

our instrument; for in the case of both Northampton and Preston I could have bought the stock for about half the price I can to-day. Then, there is this point about it. We have really had a lot of trouble in getting the large and prosperous companies to consider the matter; for when a man is doing well he doesn't bother his head much about these things. But it is a very good thing, if you are prosperous, to insure that prosperity, and to be assured that prosperity is going to be permanent. No matter how large the station is, it cannot afford to neglect the basis on which that prosperity is built. If it is built upon an inequitable method of charging, it cannot be permanent. We have in England the satisfaction of knowing that we have already got three of the large districts of London to adopt our system, and we have also the city of Glasgow, in Scotland, which is our next largest city. So we may say that in England we have been fairly successful. The big industries, of course, do say, "Well, while we are doing well, let us alone;" but I submit to you, gentlemen, who are in control of large stations, that the security of your prosperity must surely be based on your answer to the dissatisfied customer. When he comes and says, "What sort of a bill is this? I don't like it; I am paying too much," you say, "I am charging you exactly in accordance with what it costs to supply you; can anything be fairer? Surely, you cannot expect me to supply you at a loss." He may say that he will go to a rival company. Let him go to the rival company. We cannot store our commodity as the gas companies can. It is no use, gentlemen; storage batteries to-day are not very different from what they were ten years ago, and if you are going to compare the efficiency of the storage battery with that of the gasometer it won't hold water.

I heard one gentleman make the remark yesterday that the central station manager's life was not a happy one. Well, now, we rather boast at Brighton that we can always go home to tea; and we think that is a very great point. Let us have a tariff that insures us against loss on any plant. As our friend remarked this morning, let us go to bed and sleep; let us be able to say, "Well, what I have sold to-day I have not sold at a loss, anyway." If you charge a man full price for anything, up to a certain point, you know that you are making a profit. I think that point has been reached; and surely that is good enough, gentlemen.

I noticed that the point was raised among several gentlemen here this morning, was not our system complicated? Well, gentlemen, we endeavor to simplify that very much in the instrument manufacture. We have tried to follow the well-known American saying, "You press the button; I do the rest." We make our instruments and calibrate them absolutely to read directly in kilowatt hours. Give us your fixed charges, give us lamps, on the other hand, and we will tell you what the tariff ought to be.

Another gentleman this morning favored the adoption of flat rates, and said that until we got down to the gas and water level we should never be doing any good. I would just remark that it seems to me that it would be a good thing for that gentleman to go to the telephone company and say, "Now, look here, I don't like your rental, your fixed rental; I don't want it; I want to pay so much a message." The telephone company would tell him at once that that would be simply impossible. You would have two customers on the telephone;

one would be using it perhaps a dozen times a day; another might use it once a week. Now the fixed cost of getting ready to supply that man had been very great. And I might say that the fixed cost of supplying any man with sixteen-candle-power light has been very great, too; there is not a great deal of difference between the telephone analogy and the electric light supply analogy. The administrative cost of a telephone system does not bear a very great difference proportioned to the electric supply service.

The same thing applies to a great many interests in this country and in our country. You don't say, "Well, it's all the same price, good and bad; all the same price." Go to a coach hirer and say, "See here, I want your coach four hours a day; how much will you charge an hour?" He would say, "I will charge you one dollar for the first hour; charge you half a dollar the next three hours—" wouldn't he? Isn't that so? Now, then, another man says, "I want a coach at the same time as that man wants the coach; what is your rate?" "Well, one dollar for the first hour—" The man says, "I only want it half an hour." "Oh, well," the coach hirer says, "I can't afford it for less than a dollar to start in on." And that coach hirer is right. He knows very well that the fixed charges on that coach are the same whether it is used one hour a day or ten hours a day.

There is one little point about flat rates that I can quite well understand we all like; that is, that they are very smooth and sweet, and all that sort of thing, and save the agony of thought. But can a flat rate, if it competes with the sliding scale in the matter of a low price for the product, be a profit-earner?

One gentleman remarked this morning that he thought the ideal basis would be to get to gas level.

Well, gentlemen, I decline to admit that gas is an ideal in any shape or form except for heating. And I decline to admit, absolutely, that gas has any right arbitrarily to define what is the proper basis for electricity supply. All that being true, I do wish to point this out, that on a flat rate you must always make the good customers pay for the bad. That is commercially inexpedient and theoretically—well, absolutely—wrong. Now, of course, my friends and I naturally looked out for lights the very first thing on landing in your country, and what did we see? Exactly the same that we see in our own large cities. We saw gasoliers with electric lights. We saw the electric lights were out, because we didn't land until half-past eight. All gas. But there were the incandescent lamps ready. Why is this? Why is it? We went on to Boston; the same thing. In all the American cities that we have been, the same thing—that directly seven o'clock is past they all use their electric light very carefully unless they are on contract, and then they absolutely throw it to waste.

Now, your president very kindly asked me to speak in regard to the instrument. I just wish to say one thing. Of course the question of capital cost in a charge of this kind must be seriously considered. But what is, on the one hand, the importance of capital cost to a reform of your whole method of finance? What proportion does it bear to the reform of defects? In Brighton, we have improved our load factor; that is to say, the earnings per horse-power demand at the station are something like forty-five or fifty per cent. Well, we say that the cost of installing those instruments certainly did not come to more than two or three per cent on the whole of the capital. It is all a matter of finance as to what

you put in and what you get out. You spend a few thousand dollars on these instruments, and you reform, at one fell swoop, your whole method of charge; and you have a perfect answer to everybody who comes in; you have a perfect answer to your competitors. If other people are saying, "Those people are doing very well; we should like to run a rival line. What are they charging?" "They are charging," you say, "twenty cents the first hour's daily use, and after that they are only charging five cents." "Oh," says the man, "there is nothing in it; it won't pay to rival them." It is the best answer you can give to your opponents.

Now, gentlemen, you will very naturally say, "Supposing we adopt this method,—we admit that theoretically it is very sound—if we do, doesn't it mean this, that a lot of our long-hour consumers will get their bills written down, and we shall have a smaller revenue at the end of the year?" You may be sure that with our electric light companies in England that are using our system I have had that to answer before. And what are the facts? In every case the revenue has gone ahead largely. If I want any commodity, and I can afford to buy only a little of it, and someone comes to me and says, "Look here, if you will take a much larger quantity, spread your demand over a good length of time, I can afford to supply you more cheaply," well, I certainly want it. Nearly all the consumers you supply want more light. If they didn't I don't see why your pitch should come down at six o'clock. In every station I have seen, the loads go down at six o'clock. Are the people in bed? No. What are they doing? Burning gas. And they will burn gas as long as you have flat rates. We all like to buy in the

cheapest market. Now, we have made a financial success of this thing in Brighton. But, you say, we had a very small motor load to help us. You may think we are very fortunate in that respect. Don't think that any of our success in Brighton has been due to that motor load. Brighton is a pleasure town—with the exception of myself and two or three other small factors--but the horse power on motors would not be one-tenth of the whole. That is a very small factor indeed.

Now, if the system is all right, it will wait. All we ask you to do, gentlemen, is to look thoroughly into it. We are satisfied that if it is good on our side of the water it is good on your side of the water. You know we have not hesitated in the past to adopt methods from your country; we have taken them very freely. We simply ask you in this matter to look at the system. If it is good, it is good for you as well as for us. I cannot see that your conditions on this side of the water vary very much from our conditions in England. One thing is quite certain—that the sole end and aim of our work is to broaden out the load curve. We say that our business and our tariff must be so framed as to make it worth a man's while to use his light for as long as possible every day; and, in fact, instead of using two illuminants, and paying two lighting bills, use one, and that one shall be ours.

I am very much obliged to you, gentlemen, for the very patient and kind hearing you have given me.

THE PRESIDENT: The next order of business is a paper by Professor Charles A. Carus-Wilson, of McGill University, Montreal, entitled "The Induction Factor; A New Basis of Dynamo Calculation and Classification." I have much pleasure in calling on Professor Carus-Wilson.

# THE INDUCTION FACTOR; A NEW BASIS OF DYNAMO CALCULATION AND CLASSIFICATION.

The contents of this paper are, for clearness, divided into sections as follows:

I. Definition of the *induction factor* and methods of determining it experimentally.

II. Definition of the *force factor*, with examples

III. Use of the *induction factor* in Dynamo *calculation*. Motors running at a uniform speed. Examples: Street railway motor; elevator motor.

IV. Motors running at a varying speed. Examples: Elevator motor; street railway motor.

V. Use in special design. Example: The motors on the Baltimore & Ohio. Railroad.

VI. Use of the *induction factor* in dynamo *classification*. Comparison of two generators of equal kilowatt output and of two motors of equal horse-power.

VII. Classification into types depending on the form of the force factor curve, with examples.

## SECTION I

If a dynamo has A conductors on the surface of the armature, N lines of force per pole and p pairs of poles connected in series, the torque in inch-pounds for C amperes passing through the dynamo can be written

$$t = 1.41\ p\ C\ A\ N\ 10^{-8} \qquad (1)$$

When N is a constant quantity, the only variable in this equation is C; so we can write

$$t = 1.41\ C\ M \qquad (2)$$

where M depends simply upon the number of con-

ductors on the surface of the armature, the number of lines of force per pole and the number of pairs of poles connected in series, and can be expressed thus:

$$M = p\,A\,N\,10^{-8} \qquad (3)$$

If the armature rotates uniformly at *n* revolutions per second, the induced volts can be written

$$e = p\,A\,N\,n\,10^{-8} \qquad (4)$$

Thus $M = \frac{e}{n}$ and may be defined as the induced volts divided by the number of revolutions per second; we may call M the *induction factor* of the dynamo.

We must not suppose that, because M can be defined as the induced volts divided by the revolutions per second, it necessarily depends in any sense on the motion of the armature. Equation (3) shows that M depends only upon the number of conductors, the lines per pole and the number of pairs of poles connected in series, and this equation holds true if the armature is at rest, and does not in any way involve the speed.

The induction factor can be determined experimentally, either by observing the torque for a measured current, or the induced volts at a measured speed; the latter method is the most useful, as the necessary observations are so easily made.

Example 1. We wish to know the torque on the shaft of a direct-coupled generator when delivering a current of 300 amperes. We see by the tachometer that the speed is 400 revolutions per minute, while the voltmeter reads 120 volts on open circuit; dividing the volts by the revolutions per second, we at once find the induction factor to be 18, and the

required torque $1.41 \times 300 \times 18$, or 7,610 inch-pounds. Thus, by simple inspection of the tachometer and voltmeter, we can ascertain the forces acting in the machine for any given current in the armature.

If the voltmeter can be read only when a current is passing in the armature, we must, of course, make an allowance for the internal drop, since the value of $e$ used in determining the induction factor is the true induced volts.

Example 2. We have to find the pull on the belt driving a railway generator, the pulley having a diameter of forty inches. The tachometer reads 440 revolutions per minute, while the voltmeter indicates 550 volts, the ammeter reading 400 amperes. Neglecting the internal drop, the induction factor appears to be seventy-five, so that the pull on the belt is given by $1.41 \times 400 \times 75 \div 20$, or 2,110 pounds. If now the internal resistance were 0.0375 ohms, there would be an internal drop of fifteen volts, so that the true value of the induction factor would be seventy-seven, and the actual pull on the belt fifty-six pounds more than we had estimated. The pull thus calculated is, of course, that due to the current in the armature, and does not include that required to make up the core and friction losses.

## SECTION II

If for t we put T, where T is the force at the rim of a pulley of diameter d, equation (2) can be written

$$T = \frac{1}{\pi d} M C \, 10^7 \text{ dynes} \qquad (5)$$

where d is expressed in centimetres, T in terms of C. G. S. unit of force and C in amperes. If, now, the circumference of the pulley be $10^7$ centimetres, *i. e.*,

if $\pi d = 10^7$ centimetres, we can express the force of the dynamo thus:

$$T = M\ C \text{ dynes} \tag{6}$$

The force of a dynamo may thus be defined as a force of M C dynes at the rim of a pulley $10^7$ centimetres in circumference. We may call M C the *force factor* of the dynamo.

Since M is the induced volts divided by the revolutions per second, it follows that $C\ M = \frac{C\ e}{n}$; but C e is the rate of doing mechanical work; *i. e.*, the work done per second measured in watts, hence C M is the work done per revolution of the motor at any speed. If, then, we are given C and M, we can find the work per second, *i. e.*, the rate of working, or the power, by simply multiplying the product C M by the revolutions per second.

Example 3. If the induction factor of a dynamo is five, and the maximum current one hundred amperes, C M=500, and the rate of working at twenty-five revolutions per second is seen at once to be 12.5 kilowatts.

Many manufacturing firms have used the ratio of the watts to the revolutions per second as a basis of comparison of dynamos without perceiving its true significance, and have called this ratio the mass factor.

The fact seems to have been overlooked that the ratio of the induced volts to the revolutions per second is a constant, so long as the useful lines per pole remain unaltered, being, in fact, what we have termed the induction factor.

While the force factor and the so-called mass factor are one and the same thing, the latter is expressed in a way involving the idea of power and, consequently, of speed, while the former indicates the real nature of

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this ratio, showing that it is quite independent of speed, and, therefore, not a power unit at all, much less a mass unit, but a force unit.

Example 4. A four-pole railway generator, with the armature parallel connected (giving $P=1$), has 440 conductors on the armature, with $16.1\times10^6$ lines per pole; the induction factor is seventy-seven, and the force factor for 600 amperes is $77\times600=46.2$ kilodynes; the output at 450 revolutions per minute is $46.2\times7.5=346$ kilowatts; the dynamo is a General Electric Company's M. P. 4, 300 multipolar railway generator.

Example 5. A ten-pole generator, armature parallel connected with 1,440 conductors and $28.6\times10^6$ lines per pole, will have an induction factor of 412.

The force factor for 1,500 amperes is $412\times1{,}500=618$ kilodynes, and the output at eighty revolutions per minute is 825 kilowatts. The dynamo is a Westinghouse ten-pole railway generator.

### USE OF THE INDUCTION FACTOR IN DYNAMO CALCULATION

### SECTION III

The induction factor forms a connecting link between the calculation for and the construction of a motor, and since it is the true basis of the dynamical action of the motor, it can be made the subject of calculation and enter into equations of any complexity.

Example 6. We have to design a motor that will draw a car at thirteen miles an hour, with a tractive effort of 680 pounds on thirty-three-inch wheels, with gear ratio 4.78 on a 500-volt line, the resistance of the motor being 1.3 ohms. If the mechanical efficiency is eighty-five per cent, the total tractive effort T must be 800 pounds.

If E be the tension of the line, d the wheel diameter, v the gear ratio, S the speed in miles per hour, R the resistance of the motor, the induction factor is given by the following equation:

$$M=\frac{E\,d}{11.2\,v\,S}\left\{1+\sqrt{\left(1-\frac{8\,R\,T\,S}{E^2}\right)}\right\} \tag{7}$$

Inserting the given values in this equation, we find M to be 41.7. We also see from the equation

$$T\,d=2.82\,v\,M\,C \tag{8}$$

that the current, when running with the given load, will be forty-seven amperes.

So that the motor must have an induction factor of 41.7 and carry safely 47 amperes; *i. e.*, the force factor must be 1,960 dynes.

The induction factor may be made up in any way that is most convenient. If there are 720 conductors on the armature, and four poles, the armature, being series-connected, giving $p=2$, we see from Equation 3 that we must have $2.89 \times 10^6$ lines per pole. Further, if the motor is series-wound, it must have the specified induction factor for forty-seven amperes in the field winding.

Equation 7 may be written in the form

$$M=7.85\frac{E\,d}{v\,s}\left\{1+\sqrt{\left(1-\frac{R\,T\,s}{11\,E^2}\right)}\right\} \tag{9}$$

where s is the velocity measured in feet per second, and d is the diameter of the rope drum of a crane or elevator.

Example 7. We have to design a motor for an elevator where the unbalanced weight to be raised is 2,000 pounds, the velocity 200 feet per minute, the tension of the line 125 volts, the gear ratio seventy-five, the friction equal to 1,400 pounds at the rim of the rope drum, which is thirty-six inches diameter,

and the resistance of the motor 0.05 ohm; inserting these values in the equation, we find the induction factor to be 4.45, and the running current 130 amperes; the force factor is therefore 578 dynes. If p=1, and A =200, there must be $2.22 \times 10^6$ lines per pole. Since the pull at the rim of the rope drum is 3,400 pounds, when running at 200 feet per second, this motor would develop about twenty horse-power; and if the elevator had to act always at this speed, it would be sufficient to describe the motor as a twenty-horse-power motor; but this would give no information as to the ability of the motor to accelerate, since, at the moment of starting, the horse-power is nothing.

## SECTION IV

The current required for any given acceleration is given by the equation

$$a=405\times10^{-4}\times\frac{v}{d}\frac{M}{W}\times C_a \qquad (10)$$

where $C_a$ is the current required (over and above the frictional or running current) to produce an acceleration of a foot per second in a mass of W tons.

Example 8. We have to start up the elevator car of Example 7 in two seconds; *i. e.*, to get up a speed of 200 feet per minute in two seconds; *a* is then 1.67, and if we suppose the total mass to be moved to be five tons, the required current is twenty-two amperes, making a total current, at the start, of 152 amperes. The motor must therefore have a force factor of 676 dynes in order that it may start up in the given time.

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NOTE—Tons of 2,240 pounds and so throughout this paper. If tons of 2,000 pounds are found more convenient, the numerical constant can be changed.

If the distance from floor to floor were twelve feet, two seconds would thus be occupied in getting up speed, during which time the car would travel 3.3 feet, and the rest of the distance, 8.7 feet, would be covered in 2.6 seconds at 200 feet per minute, making a total time of 4.6 seconds for the whole distance. Nearly half the time is thus occupied in accelerating.

Suppose now that we had to reduce the time of starting by one-half; *i. e.*, to start up in one second. One way of stating the case would be to say that we needed a "more powerful motor"; but so long as the frictional resistances and the final speed are to remain the same, the maximum horse-power of the motor remains constant, so that we do not need more power, but more force; *i. e.*, we require a motor with a higher force factor.

We can not alter M so long as the final speed is specified, so we must double the accelerating current, making the total current at the start 174 amperes. The motor would then be described as having an induction factor of 4.45, with an armature capable of carrying 174 amperes safely; *i. e.*, the motor must have a force factor of 775 dynes.

Example 9. Take the case of the street railway motor of Example 6, with induction factor 41.7 and force factor 1,960 dynes.

The total available tractive effort was 800 pounds; allowing eighty-five per cent mechanical efficiency left us with 680 pounds for useful effort. (The well known G. E. 800 street railway motor, made by the General Electric Company, has 800 pounds available for useful effort with forty amperes.)

If the track resistance for a car weighing ten tons be 200 pounds, this will leave us 580 pounds per

motor, if there are two motors, for grades and starting, or we may say that of the maximum permissible current of forty-seven amperes, thirteen are used in overcoming gear and track friction, and thirty-four are available for grades or starting.

Now, 580 pounds are equivalent to a grade of five per cent for a ten-ton car, so that the motor would run a car of this weight at the given speed—thirteen miles an hour—up a grade of five per cent. Taking 680 pounds as the useful effort at this rate, the useful watts can be written (to within one-half per cent of accuracy) as 2 S T or 17.7 kilowatts or 23.7 horse-power. This is the maximum rate of working.

These motors, however, will not be able to start the car on this grade. They can run the car when once started, but if it should happen to stop on the grade, they can not get it started again, since the whole available current is used up in track friction and on the grade. We must draw more current from the line if we are to start up on the grade.

Equation 10 tells us that we can make the acceleration at the start anything we please, by increasing the current above that required for the grade and for friction. Let us find how much current would be required to start up in twenty seconds on a five per cent grade.

The final speed of thirteen miles an hour is equivalent to 19.1 feet per second; if we have to make up this speed in twenty seconds, the acceleration must be 1.91 feet per second, assuming uniform acceleration throughout. Inserting this value in Equation 10, remembering that each motor has to accelerate half the car, we find the required current to be twenty amperes, so that the total current from the line at the start would be sixty-seven amperes;

namely, thirteen for friction, thirty-four for the grade and twenty for accelerating. The distance traveled in getting up speed would be about sixty-three yards.

The motors then would have to be capable of carrying sixty-seven amperes, and the force factor must be 2,790 dynes.

SECTION V

When the tractive effort, the speed, the tension of the line and the resistance of the motor are given, we can write

$$\frac{M\ v}{d}=\frac{E}{11.2\ S}\left\{1+\sqrt{\left(1-\frac{S\ R\ T\ S}{E^2}\right)}\right\} \tag{11}$$

In designing a motor equipment to fulfill certain conditions, we must be able to distinguish between the part played by each of the quantities, M, v and d, in obtaining the desired result.

Example 10. A train and locomotive on the Baltimore & Ohio Railroad weigh 780 tons, and have to mount a grade of 0.8 per cent at 10.7 miles per hour. The frictional resistance of the track is nine pounds per ton, reckoning at this rate both train and locomotive. The tension of the line is 625 volts. Four gearless motors are used, permanently connected in series, each having an internal resistance of 0.0209 ohm.

Each motor thus has to move 195 tons on a tension of 156.2 volts. The draw-bar pull per motor for the grade is 3,490 pounds; for friction, 1,755 pounds; allowing ninety-five per cent mechanical efficiency, we get 5,500 pounds as the required tractive effort per motor; inserting this value together

with those for E, R and S, in Equation 11, we find the value of $\frac{M}{d}$ to be 2.32, v being unity.

It appears then that whatever size of driving wheel we employ, the induction factor must be 2.32 times the diameter; and that so long as this ratio is maintained, the locomotive will haul the train up the grade at the required rate. For instance, if we take wheels four feet in diameter, the induction factor must be 111. If d is five feet six inches, M must be 153. The current at full speed is 850 amperes from Equation 8, and is unaltered by increasing or decreasing the ratio of M to d, so that we should take d as small as possible, consistent with leaving a clearance for the motor and its attachments. The actual values of M and d for the motors in use on the Baltimore line are M=144, d=62 inches.

When running at full speed each of these motors would be doing work at the rate of 158 horse-power, so that the horse-power of the locomotive would be 632. The current from the line would be 850 amperes, as obtained from Equation 8. This current will not, however, start the train on the grade. We have to find then how much current is required to do this.

If the start is to be effected in forty seconds, since the final speed is 10.7 miles an hour, or 15.7 feet per second, the acceleration must be 0.393 foot per second. Inserting this value in Equation 10, remembering that W is 195, and $\frac{M}{d}$ is 2.32, we find the current required for acceleration to be 810 amperes, making a total current at the start of 1,660 amperes, or a force factor of 239 kilodynes. This agrees with the results obtained in starting a train of the given weight under the given conditions. (See

Mr. Lee H. Parker's paper on the "Electric Locomotives Used on the Baltimore Line", published in the *Street Railroad Journal* for March, 1896.)

### USE OF THE INDUCTION FACTOR IN DYNAMO CLASSIFICATION

#### SECTION VI

Example 11. Two generators run at the same speed and have the same kilowatt output. A is a generator giving ninety-six amperes at 125 volts, while B gives 9.6 amperes at 1,250 volts. These two dynamos differ radically, but the difference is one that their classification by kilowatt output fails to recognize. They differ dynamically, as can be seen by passing the same current through both, when the one machine will give ten times the torque of the other. This experiment can be made when the machines are standing still, so that the difference does not depend upon that of their induced volts when they are both running at the same speed, but, rather, the difference of volts depends upon the dynamical difference that exists whether they are standing still or whether they are running.

The induction factors of these machines can be found thus:

The low-tension machine has 200 conductors on the armature and $2.5 \times 10^6$ lines per pole, p being unity, so we have

$$M = 200 \times 2.5 \times 10^6 \times 10^{-8} = 5$$

The high-tension machine has 3,760 conductors and $1.33 \times 10^6$ lines per pole, p being unity, so that the induction factor is given by

$$M = 3,760 \times 1.33 \times 10^6 \times 10^{-8} = 50$$

A comparison of the induction factors indicates

the real difference between these two machines. If they are to run as generators at equal speeds and give the same kilowatt output, the current delivered by one will be ten times that delivered by the other. If they are to run as motors at the same speed with the same horse-power output, one must run on a line tension ten times that of the other.

Example 12. The motors in use on the Liverpool Overhead Railway and on the City and South London Railway are rated at about the same horse-power, but on actual test the Liverpool motor can pull over two of the South London motors when equal current is passing in all three.

The motors on the Liverpool Railway were designed to run in parallel, two motors to each car, while those on the South London Railway were designed to run permanently in series, two motors also to each car.

If the tension of the line, the speed and the draw-bar pull were the same in the two cases, the induction factor of the Liverpool motors must be twice that of the South London motors; the values were actually 120 and 60 for 100 amperes in the series winding in each case, the force factor being twelve and six kilodynes, respectively, for this current. Hence, each of the Liverpool motors must give twice the draw-bar pull of one of the South London motors for the same current, provided the wheel diameter is the same in both cases. The wheels on the Liverpool cars have a diameter of thirty-three inches, while those on the South London cars are twenty-seven inches diameter; so that the respective draw-bar pulls for one hundred amperes would be (taking the values of M as given above), for the South London motors, 630 pounds, and for the Liverpool motors, 1,030 pounds.

We must not infer from what has been said that the Liverpool equipment is necessarily more efficient than the South London equipment when running at full speed, because, although for equal speed and draw-bar pull the current per motor in the former would be half that in the latter, yet since the South

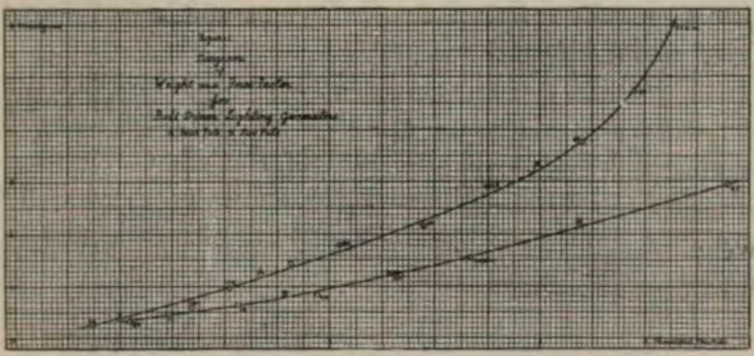

Fig. 1.

London motors are in series, the current from the line is the same.

SECTION VII

If we take the weights and the force factors of a number of dynamos belonging to the same type and plot them on rectangular axes, we obtain a series of points lying on a curve.

In Figure 1 this curve has been plotted for two types of dynamos manufactured by the General Electric Company; Type A is a four-pole and Type B a two-pole, belt-driven lighting generator. The verti-

Note—The form of this curve was first noticed by Mr. E. Wilson, in a paper recently read before the Institution of Electrical Engineers in London; the force factor is there spoken of as the mass factor.

cal ordinates give the force factor in kilodynes, and the horizontal ordinates give the weights in pounds.

The curves afford a convenient way of comparing the two types. The well known fact that the four-pole machines give a greater output for equal weight than the two-pole machines is clearly shown. The numbers against each point show the rated kilowatt output. All the dynamos in this diagram are wound for 125 volts. Equal force factors and equal speeds give equal kilowatt output.

The force factor corresponding to any weight may be made up in a great number of different ways, by taking different values of M and C.

For instance, taking a force factor of 2 kilodynes, we may have machines of equal weight with the following differences:

| C. | M. | MC. | Revolutions per minute for 125 volts. | Kilowatts. |
|---|---|---|---|---|
| 200 | 10 | 2,000 | 750 | 25 |
| 250 | 8 | 2,000 | 940 | 31 |
| 340 | 5.9 | 2,000 | 1,270 | 42 |
| 400 | 5 | 2,000 | 1,500 | 50 |

There is thus a considerable range of output for a machine of given weight, according to the speed at which it is to run. For this reason we may find machines of the same type giving equal output, but of different weights, the heavier machine running slower than it need do, if it occupied its normal position on the force curve.

Thus a dynamo of this type, giving 340 amperes at 125 volts at 1,270, will weigh 3,550 pounds, and have a force factor of two kilodynes. A dynamo of the same type, weighing 4,750 pounds, has a force factor of three, and, if required to give 340 amperes

at 125 volts, must have an induction factor of 8.83 and run at 850.

Figure 2 gives the curves of force factor and weight for different types of railway generators. A and C are made by the General Electric Company, the former belt-driven, the latter direct-connected. B is made by the Walker Manufacturing Company, and

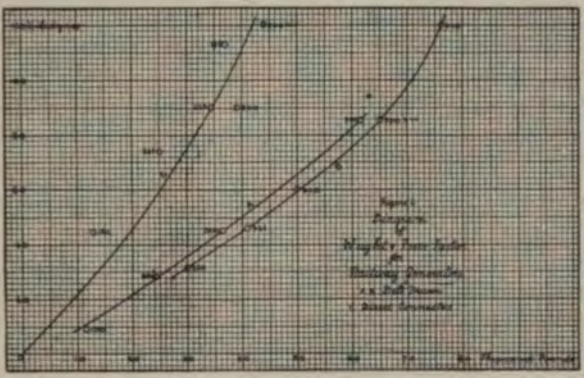

FIG. 2.

is belt-driven; the numbers opposite to each machine indicate the rated kilowatt output, all at 550 volts.

Figure 3 gives the force factor curve for the complete line of direct-connected railway generators made by the General Electric Company. The particulars of the machines are given in the table. All these dynamos are wound for 550 volts.

The vertical ordinates of the force curve represent the product of the induction factor M and the current C. If both these quantities increased uniformly with the weight, the force curve would be a straight line. The bending up of the curve indicates that either or both of these quantities does not increase uniformly with the weight.

If we plot the induction factors corresponding to each machine as vertical ordinates, the points thus obtained should lie on or above a curve giving the smallest induction factor for a machine of any weight; *i. e.*, indicating the highest speed at which

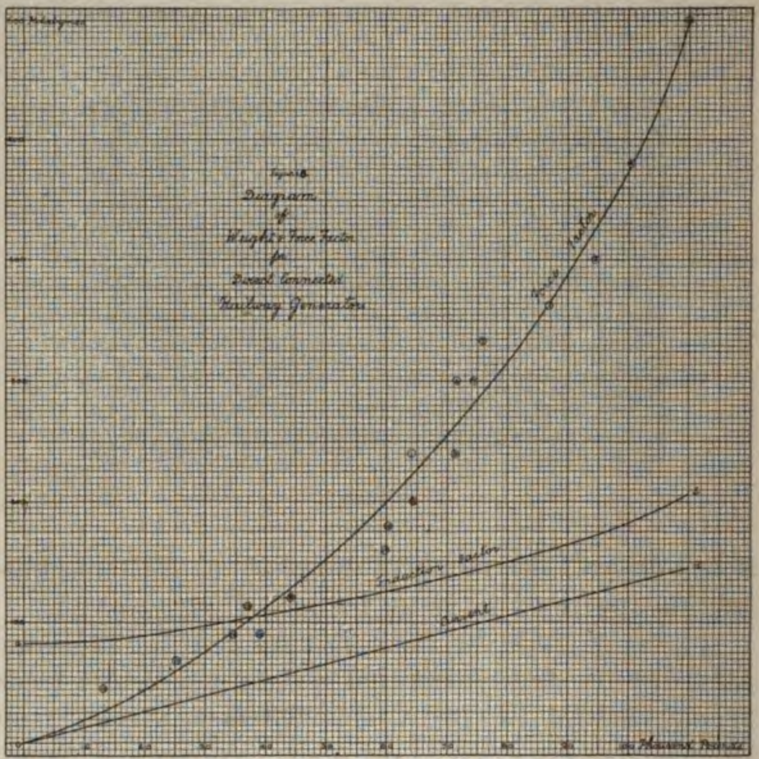


FIG. 3.

a machine of that weight may be run. The points may lie above this curve, since a dynamo of any weight can be run at a speed lower than the limiting speed, but the points should not lie below this curve. By dividing the force factor for any weight by the corresponding induction factor, we obtain a third curve

which gives the variation of the current with the weight.

In Figure 3 the curve *a b* has been drawn on the assumption that the current curve *od* is a straight line. It is probable that it is not quite straight, but it would seem that the weight varies very nearly as the current. The induction factors are plotted vertically on a scale of one inch equal to one hundred of M, and the currents on a scale of one inch equal to 500 amperes.

As an illustration of the use of the curve, let us

## TABLE

DIRECT-CONNECTED RAILWAY GENERATORS

| Poles. | No. in Diagram. | Rated kilowatt output | C. | R. P. M. | M. | M. C. kilod. | Weight 1,000 lbs. |
|---|---|---|---|---|---|---|---|
| 10A. | 1 | 500 | 910 | 125 | 264 | 240 | 64.0 |
| 10B. | 2 | ... | .... | 75 | 440 | 364 | 87.1 |
| 10B. | 3 | ... | .... | 90 | 367 | 334 | 76.0 |
| 10B. | 4 | ... | .... | 100 | 330 | 300 | 71.3 |
| 10B. | 0 | 800 | 1,450 | 80 | 412 | 600 | 110.0 |
| 10B. | 5 | ... | .... | 120 | 275 | 400 | 94.4 |
| 10C. | 6 | ... | .... | 100 | 330 | 480 | 100.9 |
| 8A. | 7 | 400 | 725 | 80 | 412 | 300 | 74.2 |
| 8A. | 8 | ... | .... | 120 | 275 | 200 | 64.3 |
| 8A. | 9 | ... | .... | 100 | 330 | 240 | 71.4 |
| 6A. | 10 | 150 | 270 | 200 | 165 | 44.5 | 13.1 |
| 6A. | 11 | 225 | 410 | 200 | 165 | 67.5 | 25.1 |
| 6A. | 12 | ... | .... | 150 | 220 | 90.0 | 34.3 |
| 6A. | 13 | ... | .... | 120 | 275 | 113 | 37.0 |
| 6A. | 14 | 300 | 545 | 200 | 165 | 90.0 | 39.1 |
| 6A. | 15 | ... | .... | 150 | 220 | 120 | 43.9 |
| 6A. | 16 | ... | .... | 100 | 330 | 180 | 60.4 |
| 6B. | 17 | 400 | 725 | 150 | 220 | 160 | 59.7 |

find the lightest dynamo of this type that will give 500 kilowatts at 550 volts.

The current is 910 amperes, and the weight, consequently, 69,000 pounds. The corresponding induc-

tion factor is 270, so that the machine must run at 122 revolutions per minute.

If we look at the list of dynamos in the table, we shall see that the lightest dynamo of this output, actually made, weighs 64,000 pounds, and runs at 125 revolutions per minute, being thus a little lighter than that indicated by the theory.

NOTE—The limits of this paper do not permit me to insert the proofs of the equations it contains. These will, however, be found in full in the work on Electro-Dynamics, which I am now preparing, and which will shortly be published by Messrs. Longmans, Green & Co., London and New York.

PROFESSOR CARUS-WILSON: I am very much obliged to the General Electric Company for having given me these data. It is quite impossible, without the aid of a blackboard and more time than we have to give to the subject this afternoon, to go into the matter in any greater detail. But those of you who have this paper, who care to do so, will like to go into the matter more at leisure; and if at any time you care to correspond with me on the subject at McGill University, Montreal, I shall be very glad to have any data you may have to give me and to have some interchange of correspondence on this subject.

MR. CLAY: I understand, Mr. President, that a discussion of this paper cannot be gone into without certain equations, and I would therefore move you that a vote of thanks be extended to Professor Carus-Wilson for the preparation and reading of this paper.

THE PRESIDENT: It has been moved and seconded that a vote of thanks be tendered Professor Carus-Wilson for the preparation of the paper that he has just read. It is difficult for us to appreciate the

amount of time and attention that must be given to the preparation of such a paper to be presented at a convention; and those of us who were at the Montreal convention, and had the pleasure of accepting the hospitality of the McGill University authorities and visiting their different technical laboratories and seeing the extent of the work that they had in hand for the advancement of the educational interests under their charge,—can fully appreciate how busy a man Professor Carus-Wilson is; and under these circumstances I think he is certainly entitled to a very hearty vote of thanks for the time and trouble that he has given to the preparation of this paper. I will put the resolution.

Carried.

THE PRESIDENT: Professor Carus-Wilson, I have to tender you the thanks of the association.

THE PRESIDENT: It is now my more than ordinary pleasure to introduce to you a very old friend; one who has stood by the association for many years, and whom we have always felt that we could call upon, no matter what his other interests might be, to be present and, not only to prepare a paper when asked to do so, but to take a very active part in our discussions. I call upon Professor Elihu Thomson to read his paper on "Recent Progress in Arc Lighting."

Professor Thomson then read his paper as follows:

# RECENT PROGRESS IN ARC LIGHTING

It is now six years since I read a paper on "The Electric Arc and Its Use in Lighting" before this association. In that paper a general outline of the history and nature of the electric arç was given, together with a number of considerations relating to the arc as a source of illumination. The means for supplying current to the lamps and controlling the feed of the carbons were also touched upon.

Since that time considerable technical advances have taken place in this important field, and a continuous commercial expansion of arc lighting as an industry has resulted.

The purpose of the present paper is not, however, to deal with the commercial aspect of the case, except in so far as it is evidently the result of the improved devices which have been brought out in the past few years. In looking over the ground we find, also, that it is certainly not possible to deal very comprehensively with the several divisions of the subject within the limits natural to a paper such as the present one is intended to be. Should it serve as a foundation on which a general practical discussion of the various topics can be based, the writer's purpose will have been fulfilled.

We have, to-day, in actual commercial use arc lamps running under quite a variety of conditions as to nature of current, regulation of the current, and conditions concerning the arc itself as a source of light.

According to the manner in which the arc lights are worked on an electric circuit, we are enabled to make several general divisions, about as follows:

Series arcs on
- Constant, continuous-current circuits.
- Constant, pulsating-current circuits.
- Constant-potential, continuous-current circuits.
- Constant, alternating-current circuits.

Single arcs on
- Branch of constant-potential, continuous-current circuit.
- Branch of constant-potential, alternating-current circuit.
- Compensators with alternating current.
- Constant-current transformers.

The above schedule will cover most of the practical cases that have hitherto arisen, and each case can be considered both in its relation to the use of an open arc, an inclosed arc or a partially inclosed arc.

It will, at this time, be scarcely necessary to dwell upon the main features of several of the cases above enumerated, as they are too well known to call for comment here. Thus, the case of arcs in series upon a continuous, constant-current circuit is the oldest and best known. It has the peculiar merit of permitting economical transmission by currents of potentials of several thousand volts; gives ease of regulation and great simplicity of circuits and connections, and does not demand the highest grades of carbons for the open arcs. On account of the relatively higher potential demanded by an inclosed arc, or a partially inclosed arc, and the consequent restriction of the number of lights in a series with a given permissible

voltage, there has naturally resulted thus far very little real commercial use of series inclosed arcs, and where they have been on trial use they have, in most cases, so far as the writer is aware, been discontinued.

The dynamos for constant-current arc lighting are not, of course, so efficient as high-class, constant-potential machines, but as the running of arcs with constant-potential, continuous currents demands that, for steadiness or stability, dead resistance or other additional apparatus, more or less wasteful of energy, be used in the lamp branches, what may be gained in one way is likely to be lost in another. And this remark, it will be found, is applicable still more generally in the comparison of methods of working arc lights.

In recent years the tendency in series arc lighting with constant current has been to increase of voltage of the dynamo, and machines capable of working 125 to 150 arc lights in a series have been developed successfully. But the potential between terminals in such a case may be 7,000 volts—often too high for security, and in some places forbidden by special legislation. An ingenious method of employing such machines when, as is the case with the Brush machine, several commutators are present in series relation, has been devised by Mr. Green, of the Brush company. This plan demands that separate pairs of wires be run from the machine to the switchboard for each circuit, but the unquestionable effect of the new connection is to limit the difference of potential which is possible to be manifested between any two parts of the circuit through the machine and lamps. A simple diagram like Figure 1 will make the connection and its general effect on the distribution of potentials clear to those who may not have given attention to the subject.

Let F be the field circuit of the dynamo; we may for simplicity, neglect its resistance and that of the wire of the circuit. If $C^1$, $C^2$ and $C^3$ represent the sections of armature conductor, and $L^1$, $L^2$, $L^3$ the series of lights connected between the commutators of the machine, it will be seen that each armature section, $C^1$, $C^2$, $C^3$, with its appropriate commutator, acts to produce a difference of potential, which may be represented by the vertical $a^1$, $b^1$, $=$ $a^2$, $b^2$, and $a^3$, $b^3$, while the fall of potential through each series of lights, $L^1$, $L^2$, $L^3$, results in bringing the line potential down, as it were, for another

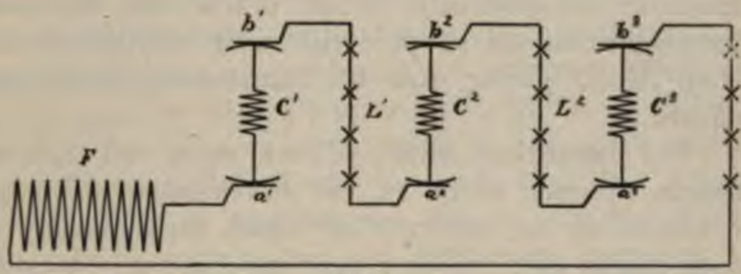

FIG. 1.

raising. In such a system, evenly loaded, the highest difference of potential anywhere to be found will evidently be that required to run a series of lights looped between two successive commutators. If lights are cut off from any set or loop, the potential difference between the terminals of that loop falls accordingly without any corresponding or proportional rise between any other parts of the circuit. If, however, lights are cut off one set and added to another, so as to keep the machine in full work with unbalanced loads, then the potential distribution is, of course, disturbed, and the system approaches the condition of all commu-

tators connected directly in series, and the lights all in one series—the old plan. Where the conditions of the circuits leaving the station are such as to permit inductional effects on parallel wires—such as those of a telephone system—the new plan of circuit connections may give, as appears to have been already noticed, a greater inductive disturbance. This must be owing to the relatively simpler commutation per loop of lamps. In the old series connection all the commutators in series acted virtually as one of many segments, which tended to give a smoother potential, or prevent waves in the potential of the line. In the new plan each commutator of few parts acts, in a measure, independently of the others, and impresses its own variations of potential more directly on the lamp lines, giving rise to electrostatic inductional effects.

The immediate future of the series arc lighting system appears to be in the development of large dynamos, up to, say, 300 arc lights each, running at such speeds that one or a pair may be easily coupled directly to the shaft of a moderately high-speed engine. The use of a regulated constant current in the series system, besides giving a simple system as to wiring, etc., is seemingly best adapted to the use of the cheaper carbons. For extended districts the series arc lighting system is still likely to hold its own, but displacement by constant-potential arcs and inclosed arcs on constant-potential circuits will doubtless continue in cities supplied by underground low-pressure systems with continuous currents.

While it is true that in the open coil types of dynamos—such as the Brush and Thomson-Houston—the current, as set up by the armature, must necessarily be wavy, still it must be borne in mind that the field mag-

net coils, the line and the series lamp magnets have, together, a considerable inductance, the effect of which is to smooth out the minor fluctuations, so that the current becomes fairly uniform. A slight tremor in the current, with differential magnet lamps, is an assistance in preventing tardy feeding. In the pure shunt type of lamp, this is of less effect on the feed.

It has been thought by many that arc lamps are interchangeable (if made or adjusted for the same current) from the circuit of one type of series arc dynamo to that of another, without difficulty. In a general way this is true, but not by any means necessarily true. Thus, an arc machine may easily have that proportioning which enables it to run a circuit of differential lamps at a certain current strength and be wrong in proportioning for pure shunt feeding lamps, such as the Thomson–Rice M. & K. The latter require a more rapid droop in the curve called the "characteristic" of the dynamo, than the differentials. Also, it may happen that a dynamo which will take a certain load of differential lamps at a certain strength of line current, can only work with satisfaction on pure shunt lamps with a ten per cent to twenty per cent increase of line current, and fewer lamps in series. In this case the differentials secure a stable current when working on a part of the characteristic curve back of that where the heavy droop occurs, D Figure 2, while the shunt lamps are only given stable current at S. Instability or quick rise and fall with flashing and possible intermittent extinguishment otherwise result.

On the other hand, any circuit of pure shunt-feed lamps will take differentials adjusted for the same current without difficulty. But in such case, if the current fluctuates in value and there be but few

differential lamps on the circuit, with a large proportion of the shunt-feeding type, the differentials are the ones to suffer and not the others. The former are sensitive to current variations, the latter indifferent thereto.

There is neither time nor space to devote to the details of arc-lamp mechanism for constant-current circuits, though much might be said in regard to the proportions that should be given to the parts, the

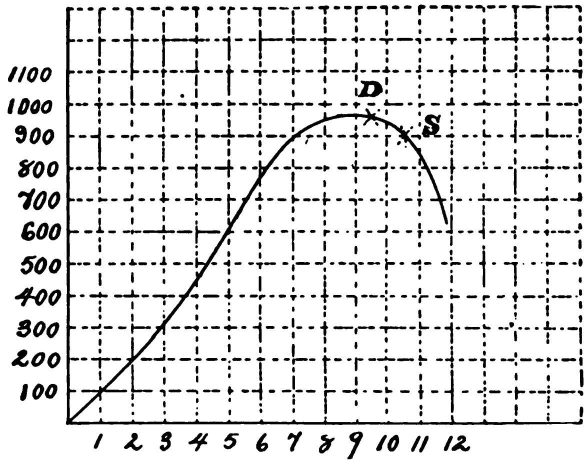


FIG. 2.

character of pull to be secured in the magnets controlling the lamp, the securing in clutch lamps of a slow or "sneak" feed (as it is sometimes expressively, if not elegantly, termed) for the carbons, the cut-out switch, etc., in both differential and shunt-magnet-control mechanism. There are two points, however, which may be touched upon in this connection, as tending to secure the best results. First, the variation of pull for a given variation of current in the magnets

controlling the lamp should be as great as possible. Second, there should be as little as possible variation in the force required to feed or recover from feeding. The force required to be imparted to the mechanism to release the clutch, detent or escapement should be as little as possible, and but a very small fraction of the total magnetic force in a differential or shunt-feeding system. Otherwise, the lamp will not be a sensitive feeder. Lamps are frequently found which form their arcs well enough, but hang up or delay at the feeding point, the action of feeding being preceded by quite a rise of potential between the carbons

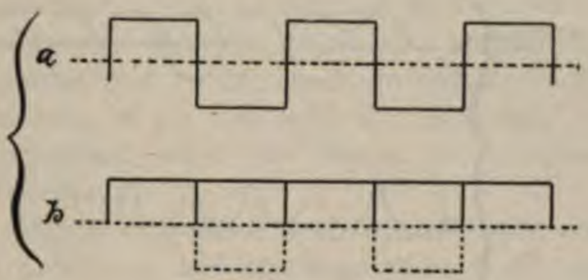


FIG. 3.

at the arc. This is owing to too much force being required to unclutch or release the mechanism. A good lamp should feed on a variation of three to five volts, and, with certain constructions, a feeding action within one-half to three-quarters of a volt variation for a 45-volt arc can be readily attained.

Passing now to the consideration of the use of pulsating currents in arc lighting, it may be said that at present little or nothing has been done commercially in the United States in the use of such currents. The subject becomes one of importance in connection with what are known as rectifiers. These are machines

that take an alternating current and commute the waves, or rectify them, so that the flow of current is in the same direction always, though rising from zero to a maximum for every alternation in an alternating current. The more or less near approach to continuity of current will depend upon the shape of the wave rectified. A rectangular wave, properly rectified, would, as in Figure 3, give a true continuous current. Other forms of wave give less continuity, depending on the sharpness of the individual wave peaks, *c*, *d*, Figure 4. The character of arc produced by the rectified

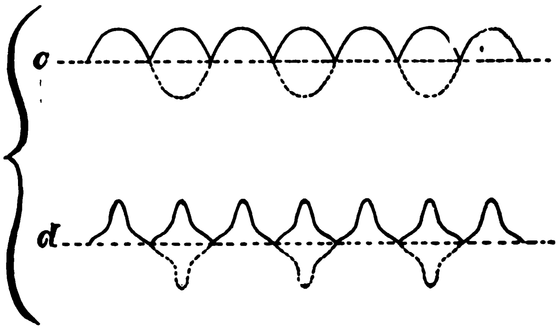


FIG. 4.

current resembles closely that of the continuous-current arc, in that the crater in the positive carbon is present, and the negative tends to point itself. There is, however, a strong note or sound evolved from the arc, depending for its pitch upon the periodicity or frequency of the alternating current. The inductional effects of the pulsating currents in lines upon neighboring lines will, of course, resemble those of alternating currents, though less musical than the latter when a sound results, as in a telephone. In order to make it easy to commute or rectify such a high

potential of alternating current as would be needed to feed, say, a series of forty to fifty arc lamps with pulsating current, certain conditions are very desirable. One of these is that the current to be rectified should be of constant value, though alternating. The writer showed, nearly ten years ago, how a constant-current transformer could be made, using primary current at constant potential to obtain secondary constant current. One of the ways was to so mount a secondary coil, with relation to its primary, that repulsion might be exerted between them and so move one away from the other when a tendency to increase of current in the secondary took place. This method was found to be highly efficient, and was embodied in a number of forms of apparatus, some of which were employed to feed constant current to arc lamps in series. In this case lamps may be cut out and the secondary coil even short-circuited, while the current in it remains practically constant.

When such a current is rectified, the same characters are preserved, and the regulation is all that could be desired for all loads within the capacity of the apparatus. The efficiency of transformation is also quite high, and the apparatus is not of excessive size for a given output. A simple commutator, revolved by a properly constructed synchronous motor, with its arc-machine brushes and air-blast, complete the machine. By the use of the air blast a single commutator, as in the Thomson–Houston arc machines, serves to rectify a single alternating-current wave of sufficient potential for up to fifty or more lights in a series. Without the air-blast, flashing would be likely to be serious at fifteen to twenty lamps in a series.

The above relates to the rectification of a single-phase current. When, however, two-phase or three-

phase currents are to be rectified, there will be at least two or three constant-current tranformers, one for each phase, and the secondary current may be combined through commutators resembling those of the Brush arc dynamo for the two-phase, and the Thomson-Houston for the three-phase. In such cases the resulting rectified current is much more nearly a steady or smooth current, and not so much of a pulsating character. This is, of course, owing to the relation of the phases being such as to cover each other's zeros or to overlap. Under proper working conditions there should be a certain field for the use of rectifiers in the United States, as well as in England, where Ferranti has for some time past had some of them in use. It is difficult to adapt a rectifier to periodicities of as high as 125 per second, but with sixty periods the problem is comparatively easy. The use of rectifiers has the one great advantage of permitting the generation of current in a station to be by means of large direct-connected dynamos, a portion of the output of which is used in the ordinary way to feed lights, etc., through the usual constant-potential transformers, while another portion, feeding rectifiers, supplies the arc lamps of the system instead of special arc dynamos, while, if needed, the whole capacity of the generator may be utilized for one or other kind of load, as desired.

The arc lamps worked by rectifiers are like continuous-current arcs in giving the downward distribution of light from the positive crater, a feature of great value in street lighting. There is also complete regulation—such that lights may be cut out *ad libitum* by shunting, while the other lights remain unaffected. Furthermore, the efficiency of the rectifier is high, and may easily be made over ninety per cent.

Two or more arc lamps are now often connected in a branch across constant-potential mains or supply lines. Thus, on 110-volt circuits, two lamps using about forty-three to forty-five volts each, and with a proper choking resistance, may be found in the branch. On 220 volts there may be four lamps in a series, and on railway circuits of between 500 and 600 volts nine to eleven lamps may be found connected, with, in each case, a proper resistance. The inevitable use of a choking resistance in series, with arc lamps run from constant-potential lines, is now pretty generally understood. Without it the current in the lamp branch is unstable, owing to the fact that the resistance of an arc is not a definite quantity, but varies for a definite length of arc in inverse ratio to the current flowing, or even falls more rapidly than the current increases, or vice versa.

Therefore, the current strength of the arc lamps in this case is not to be regulated or controlled by adjustments of the lamps alone, but by means of the variation of the choking resistance in addition. The object in each case is to set the value of the resistance at such an amount as will, when the arc lamps are adjusted to feed at, say, forty-four volts, with good cored carbons, give the desired value of current and stability of current. The quality and character of the carbons used has a decided effect on the results as to steadiness and uniformity in constant-potential arc work. Hence, a good cored positive and solid negative are desirable. The writer has seen no more perfect result in arc lighting than can be obtained on constant potentials, with good lamps and carbons burning open arcs. Much was said, and some considerable amount written, a few years ago about lamps in series on constant potential robbing each other, so that when one was

bright the other was dim, and the reverse. This phenomenon does not occur with properly constructed lamps, which are sufficiently sensitive feeders. Lamps for this service, capable of feeding within one volt variation at the arc, are in use, and the steadiness and reliability obtainable is all that can be desired.

In regard to "inclosed arc lamps", it may be said that they are beginning to be applied in a series of five upon circuits of 500 volts potential, but the consideration of this type of arc will be deferred till later, when the subject of single lamps on constant potentials is discussed.

The distribution of current for arc lighting at constant potentials has undoubted advantages, one of which is the relatively low tension and absence of danger. Another is the facility of installation along with incandescent lights, and ease in metering the supply. The loss of energy in the distribution may, at full load of lines and moderate distances from the supply station, be, say, ten per cent or more, chargeable chiefly to feeder drop, and about fifteen to twenty per cent in dead resistance in the lamp branch. We may take, then, twenty-five per cent as an average loss in reaching the lamps. This loss, which is much greater than the percentage of loss on the series system, is yet largely, if not wholly, made up by the superior efficiency of the constant-potential, low-pressure generators of large capacity over that of arc machines of relatively smaller output, and by the higher engine efficiency which may readily be attained in driving large generators, especially when working with economical loads. It must not be forgotten, however, that for equally good results a better and more expensive carbon will be required for constant-potential work than for plain series arc lighting. These obser-

vations relate, of course, to ordinary open arcs with full supply of air reaching the hot ends of the carbons. The conditions existing with long-burning lamps or inclosed arcs will be alluded to later.

One serious objection to the arrangement of lamps in series between constant-potential mains, especially those of 220 to 500 volts, is the inflexibility, or inability, to cut off some lamps in a branch without substitution of equivalent resistance, which substitution, of course, means that the same watts are consumed whether the lights burn or not. We lose the advantage of the constant-current system, which enables us to shunt lamps and save power, and also that of the simple multiple arc or parallel system at constant potentials, in which each lamp is in its individual branch circuit. Open-circuiting the branch extinguishes the light and saves power. With alternating current at constant potential there is greater flexibility, but, unfortunately, no alternating-current arc lamp is likely to equal in its effects lamps making use of continuous currents or undirectional currents.

There are two ways in which alternating currents may be used to work arc lights in series. We may either take a constant-potential system, such as one with main lines at 1,000 volts and connect between them a series of arc lamps at about thirty volts each and about thirty-five lamps, or we may transform so as to feed the lamps in series with a current of constant value, or with a current which does not vary more than a given per cent from light to full load—fifteen per cent, for example. In the former arrangement some provision must be made to allow lamps to be extinguished without breaking the circuit, and this can not be done by shunting, unless equivalent resistances be substituted, for the shunting of a lamp or

lamps in a series would result at once in a great increase of current in the others and a serious departure from normal working.

By shunting each lamp in the series by a specially constructed and carefully proportioned reactive coil, wound upon a laminated core, the difficulty just pointed out is obviated with but small sacrifice. The reactance of the shunting coil is adjusted to give, when two to three amperes of current traverse it, a potential between its terminals just sufficient to work the arc lamp which it shunts, and the gauge of wire of the coil must be ample to carry the full current of the line, for, in this case, the arc lamp is extinguished by simply open-circuiting it, while leaving the reactance in circuit. It is also necessary that the iron core of thc coil shall be at, or near, magnetic saturation when the arc lamp is burning, so that its reactance shall not greatly increase when, by accident, the lamp fails to feed or it is purposely open-circuited and the coil has to carry the full line current. In such a series, provided with shunting reactances, the ordinary series magnet in the lamp, for separating the carbons to form the arc and regulating the same, is all that is needed, since the variations of current alone are sufficient to serve the purpose, no shunt or differential magnets in the lamp being called for. It will be understood that the apparent energy consumed in the reactances is not, in fact, wasted, for the phase relation of the current is such as to make the current in the coils approach a wattless current or one with a low-power factor. For example, a coil which shows two and one-half amperes of current and thirty volts, or approximately seventy-five watts, may, in reality, not consume more than ten to twenty watts. Another way of accomplishing even a better result, but one which

requires that shunt or differential magnets be used in regulating the feeding of the carbons, is to substitute, by a special switch, a proper reactance in place of the lamp when it is to be cut out, and also to cause the lamp, on a failure to feed, to cut in as a substitute for itself this reactance. In such a case the construction of the reactance may be such as to waste very little energy, but the existence on a system of a considerable number of arc lamps and many reactances, which would be the case when a large proportion of lamps were cut off, would have the effect of loading the system with inductance to an extent which might interfere with the proper regulation of potential at the generator. In any case, these systems of working may be set aside as not having reached any decided commercial importance. They are mentioned here by way of comparison, as they present instructive features.

When a transformer is so constructed that there may be a considerable magnetic leakage, as it is termed, between the primary and secondary coils, it approximates what is called a constant-current transformer. It will, if connected by its primary terminals across mains at constant potentials, give a secondary current which, even at short-circuit, is only a moderate percentage in excess of that given when the secondary is carrying a considerable load.

In fact, such a transformer has an analogy, which is unmistakable, to a direct-current arc machine with a drooping characteristic, before alluded to. When, however, the amount of magnetic leakage in the transformer is carefully proportioned, or when, as in the rectifier transformer with repelled movable coils, the leakage is allowed to adjust itself, a substantially unvarying value of alternating current is

delivered at all loads from short-circuit up to the full load, or highest available working potential. The transformer then resembles an arc machine with an instantaneously acting and perfect regulator, or such a machine with a characteristic curve which droops vertically. This would mean the preservation of the same current at all potentials. By properly proportioning an alternating-current dynamo, the same property of constant current has been given to the machine.

For arc lamps in series on alternating current, this constant-current property is perfectly adapted. But in this case the regulation of the lamp must be by a shunt magnet responding to the potential across the arc, and not to the current passing through it, which is constant. Of course, the shunting reactances before mentioned might be used, but these would have no particular function in this case, since the system of supply permits free shunting of the lamps, and the current is the same even down to short-circuit. Numbers of lamps were installed several years ago by the Thomson-Houston company, and worked in the way indicated, the transformers being of approximate constant-potential property, but the writer does not know to what extent they are still in use. That the system is not entirely dead was indicated by a recent demand for additional transformers of the same type, though for quite a period none were supplied or asked for. The system has its merits, like the series arc system with direct currents. It does not demand the highest grade of carbons, and the lamps are not liable to chatter at starting.

Further consideration of the nature of an alternating arc in relation to the light-giving effect and to the mechanism which must be used to control the lamp, carbons, etc., will be given later.

We may now consider the use of single arc lamps on the various circuit arrangements adapted to their supply. With the ordinary constant-potential, continuous-current circuits of about 110 volts, it is manifestly not desirable to operate a single lamp, taking, say, from forty to fifty volts, and waste the remainder in resistance; yet, oftentimes, it is quite undesirable that two lamps in series be connected to the mains, on account of the inability to use one or both, and one may be quite enough. The gap is filled by the "inclosed arc", and, at the same time, the necessity of frequent trimming, a disadvantage with the open arc, is obviated. The inclosed arc lamp, broadly speaking, is an outcome of the ability to secure very nearly pure carbons, or carbons containing little or no ash and particularly free from such metals as iron, the oxides of which are deep black or brown, which would soon obscure the small globe around the arc.

The inclosed arc of to-day merits more than a passing consideration, on account of the general interest which has arisen in regard to it among electric light engineers. The idea of burning an arc in a practically closed and relatively small glass chamber is quite old. It was known also that the carbons would burn blunt or nearly square on the ends, and would require a relatively wider separation to let the light out; that they could be made to burn relatively more or less pointed by letting in more or less air. Early experimenters in this field were met at the outset by the serious difficulty of obscurations of the inclosing vessel by deposits generally brownish, and probably due to oxide of iron, the iron being present in the graphitic carbon used in forming the carbon sticks. The writer met this difficulty in 1879, and for many years after that date there were not to be found such pure

carbons as would give so little deposition as is required to work an inclosed arc practically.

Curiously enough, as late as about 1890, there was a revival of the inclosed arc as applied to arc light circuits in place of the ordinary series arc lamp. The sealing of the arc, so to speak, was such that about sixty-five volts were required to work it. A saving of carbons was effected, but the number of lights obtainable from an arc dynamo of any given capacity was seriously reduced, as was also the commercial value of any arc-light line whose potential was limited either by law or circumstance. Contrary to the original expectation of its promoters, the use of inclosed arcs on series circuits did not progress rapidly and soon retrograded. Many causes, besides the one of reduced capacity of lines, had undoubtedly an effect. Cheap carbons for open arcs, impure carbons for inclosed arcs, breakage of inner globes—resulting in rapid consumption of carbon—obscuration of light, etc., must have contributed largely to the result.

When it is remembered that, to get the best results with arc lamps on constant-potential circuits, the use of rather expensive cored carbons is necessary, the saving of carbon and frequent trimming becomes a very important item and permits the employment of more expensive carbons, provided they last long enough. The high voltage demanded by the inclosed arc was soon seen to be not a disadvantage, but a positive advantage for constant-potential circuits, inasmuch as it permitted the use in one lamp of a larger fraction of the total—generally 110 volts. Hence, instead of keeping down the potential, it could even be raised from sixty-five to seventy-five or to eighty volts with advantage. In fact, it may be that the

exclusion of oxygen has the effect of enriching the arc flame itself, in much the same way that a slightly luminous blue flame of a Bunsen burner becomes far more luminous by cutting off the air. There may, in fact, be free condensed carbon particles in the outer layers of the arc stream highly heated and, therefore, strongly luminous. The flat ends of the carbons tend, also, to cause the hot gases to be retained under the positive end, thus extending the heat of the crater and increasing the luminosity. The result of the almost complete exclusion of oxygen is that very little combustion takes place and the life of the carbon is therefore much extended. The function of the small glass vessel around the arc is not only to keep out the air, but, in addition, to act as a diffuser of the light evolved, and in this sense replace, to a considerable extent, an opal outer globe of large dimensions, necessarily thick and highly absorptive. The inner globe around the arc is made thin, to withstand heat without cracking from sudden changes of temperature, and is generally of clear glass with a thin coating, either internal or external, of an opal or alabaster-like glass, which, by the materials employed in its composition, gives a large diffusive effect without undue absorption. The inner globe is often also given a yellowish color or absorptive effect for the disagreeable violet rays, of which the long arc flame is so strong a source.

Owing to the traverse from side to side of the arc between the square ended carbons, the direction in which light is emitted from the arc most effectively is undergoing continual and very great changes, so that the intensity of light in any given direction may, in a few seconds, vary several hundred per cent, and with a perfectly clear glass inclosing globe

this variation would not only be quite noticeable, but in many cases intolerable. The diffusive power of the glass, however, is such, in the case of the opal coating, that the traveling of the arc is, in large measure, compensated, and the general effect is that of a very steady, uniform light. Were it not for the diffusive power, the color of light, as well as the intensity, would change greatly; as when the arc happened to be on the side of the carbons away from the observer, the light would then be in greater proportion from the purple or violet arc flame, and less from the glowing ends of the carbons themselves.

The carbons to be used in an "inclosed arc" should be of the very highest grade as to purity, not too hard or dense, as straight as possible, uniform in diameter and circular in section, and should be obtained of as near a standard diameter as possible, so as to avoid the necessity for adjusting the caps of the inner globes to the size of the carbons. It is necessary that the caps should fit pretty closely around the carbons to avoid leak and consequent reduction of life. Leaks of air into the inner globe must be carefully avoided, if any reliance is to be placed upon a lamp for a given run without recarboning. During the run the upper part of the inner arc-inclosing globe is coated slowly with a deposit, nearly white in color when the carbons are free from iron, and consisting of what little mineral matter has been left in the carbons. Fortunately, the hot uprising currents from the arc deposit considerable of this on the cap above and return to the arc to be re-heated and again circulated at a little above the level of the arc itself, and, as the lower carbon consumption gradually causes the arc to descend, the light of the arc continually reaches portions of the glass wall which

have been but slightly obscured by the deposits from prior burning. In general, the deposit which forms on the inner globe can be wiped off or dusted off at the time of recarboning. Carelessness in this particular may easily result in a large proportion of the light of the arc being lost, and, what is perhaps worse, the radiant heat and light of the arc, being unable to escape, goes to overheat the glass of the inner globe, either melting or deforming it so as to produce leaks, cracking it directly or burning the deposits into its surface. After this they can only be removed by such agents as hydrofluoric acid applied to the surface.

The mechanism of an inclosed arc lamp to be run singly in branches from 110-volt circuits is naturally very simple. Since the lamp regulates entirely by variations of current on its circuit, a simple series magnet suffices. No cut-out other than a fuse in the lamp branch is needed.

The switch is a plain open-circuiting switch. A choking resistance is mounted on the lamp or elsewhere in the branch, the drop over which is about thirty volts. The upper carbon or its holding rod is acted on by a simple positive clutch. There is required, however, even in such a lamp, so apparently simple in itself, great care in proportioning the parts and their relative actions, to secure the best results. If the constructor fails in any detail, the behavior of the lamp soon tells the story—the current is interrupted frequently; the voltage around the arc varies greatly; the current, as well as the light of the lamp, varies.

In the use of "inclosed arcs" instead of "open arcs", one does not escape from the necessity of using in the branch with the lamp a choking resistance. A constant-potential circuit of forty-five volts will not

supply current to arc lamps demanding forty-five volts at the terminals and approximately the same at the arc. By the use of resistance in circuit, however, and sufficient additional potential, the current, otherwise "unstable", becomes "stable", and the arc stable. It is possible, indeed, with especially sensitive lamp mechanism, to replace a part of the resistance needed by inductance, and thus save some energy. The "inclosed arc" also demands a sacrifice of energy in resistance, for a circuit of eighty volts constant potential will not run eighty-volt arcs.

For the purpose of discovering the minimum drop of potential required to exist over a dead resistance in circuit with arcs on constant-potential mains, the writer instituted and had tabulated a series of tests in which the resistance in circuit with arc lamps was gradually cut down along with the line voltage, while the current and voltage of the arcs were maintained the same. A set of tests was made with two Thomson '93 lamps in series, using at one time plain National carbons, and at another a cored upper of one-half inch diameter, and solid lower carbon of one-half inch diameter. Also a set of tests was carried out with eighty-volt inclosed arc lamps adjusted for currents of different amount at different times. During each test the line voltage was lowered and resistance cut out until instability of arc and current resulted, while up to that time the current and voltage of the arc were kept the same during the particular test.

The general result of these tests was as follows:

TWO '93 ARC LAMPS IN SERIES, WITH VARIABLE RESISTANCE.

One-half inch National carbons.

With 45 volts at each arc and a current of 9.6 amperes in the lamp branch, line voltage could not be reduced below 110 volts. This would give a drop of 20 volts over resistance and lamp magnets.

With 45 volts at arcs and 7.9 amperes, the limit was reached at 108 volts on the line.

With 46 volts at arcs and 6 amperes, the limit was 108 volts on the line.

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### TWO '93 ARC LAMPS IN SERIES, WITH VARIABLE RESISTANCE:

Carbons, ½-inch cored upper; ½-inch solid lower.

With 46 volts at arcs and 15 amperes current, the limit was 106 volts on line.

With 46 volts and 12 amperes, the limit was 104 volts on line.

With 46 volts and 9.4 amperes, the limit was 108 volts on line.

With 45 volts and 7.3 amperes, the limit was 104 volts on line.

With 42 volts at arcs and 6 amperes, the limit was 98 volts on line.

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### TEST OF 80-VOLT INCLOSED ARC LAMP, WITH VARIABLE RESISTANCE IN ITS CIRCUIT.

Solid upper and lower $\frac{7}{16}$-inch "Electra" carbons.

With 75 volts at arc and 7 amperes, the limit of line voltage was 88 to 90.

With 74 volts at arc and 6 amperes, the limit of line voltage was 92 to 94.

With 75 to 76 volts at arc and 5 amperes, the limit of line voltage was 92 to 94.

With 78 volts and 4 amperes, the limit of line voltage was 98 to 100.

With 76 volts and 3.2 amperes, the limit of line voltage was 100. (Carbons, $\frac{5}{8}$-inch "Electra".)

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The above tests are, doubtless, sufficiently accurate to show the main point very clearly. This is that a certain line voltage as a minimum is absolutely necessary in working arc lamps on constant-potential lines, whether they be open arcs or inclosed arcs. Thus, two forty-five-volt arcs in series, with uncored carbons like the brand known as "National", can not be safely worked below 110 volts on the line with resistance in series with them. More than 110 volts should, of course, be maintained for safety of the service.

The tests show, also, that, with a cored upper carbon, the limit is lowered several volts on the average, and it is known that the voltage of the arcs may be safely reduced somewhat when cored positives are used.

It is also shown that a seventy-five to eighty-volt arc, run upon a constant-potential line, is stable at considerably less line voltage than the open arc. It would appear, also, that, with either open or inclosed arcs at ordinary current strengths of from five to ten amperes, the steadying resistance in the branch is required to cause a drop of about fifteen to twenty volts, or waste energy at the rate in watts of fifteen to twenty multiplied by the amperes of current used in the lamp.

What the development of the art *would* have been if the voltage of our incandescent circuits was, as

originally set, say, ninety volts, instead of 110, is a subject for meditation.

With inclosed arcs on continuous-current circuits, as with open arcs on similar circuits, the chief source of light is the positive crater, and the downward emission is, of course, favorable to their use in illumination. This tendency to throw light downward is, in the inclosed arc, modified by the diffusive action of the inner globe, which tends to scatter the light received by it in all directions—upward, downward and horizontally.

The running of single alternating-current arc lamps on constant-potential circuits is facilitated by the ease with which, by a transformer or compensator, the potential required for the lamp may be obtained. It was natural that, when arc lamps came to be used on constant-potential, continuous-current circuits, a demand for lamps which would work upon alternating circuits fed by transformer secondaries should arise. While in the direct-current systems the potential was definite and practically could not be adapted to the lamp, in the alternating-current case transformation was easy, as by the simple device of a compensator the line voltage could be raised or lowered to suit that demanded by the lamp. An arc lamp compensator is simply a laminated core bearing a coil divided into sections with connections carried out between the sections. If the self-induction of the coil is proportioned for the secondary circuit voltage in a transformer system, as for 110 volts at the ends of the coil, circuits of thirty volts may be obtained by taking three-elevenths of the turns as a secondary; that is, by connections which include between them any turns of the coil which equal three-elevenths of the total, or which give thirty volts. Moreover,

several connections of the kind may be made to the same coil anywhere between its ends, provided that the wire included between the two connections for one lamp circuit is sufficient to give the requisite voltage. Further, the sections of wire thus chosen may overlap each other, and portions of the compensator coil thus appear to be doing double or treble duty. Whether the current be furnished direct from the secondary of a transformer or through compensators, the lines led to the lamps are of constant-potential character, and the lamps have to be adapted thereto.

An alternating arc is peculiar, and different from the continuous-current arc in a number of important particulars. The fact that the arc is extinguished between successive alternations at the zero points of the current wave, and at a rate equal to double the periodicity, results in the musical sound of the arc, which may become a source of annoyance. The same cause gives rise to difficulty in starting the arcs without having them chatter, for until the carbons get strongly heated the arc is not re-established after extinguishment with the carbons separated. With cold carbons, the carbons must touch each other after an extinguishment at the zeros. Hence, the carbons must be separated very slowly, while a large current flows so as to strongly heat their ends, or a higher potential than that to be used in running the lamp after starting must be applied at first. Another way is to employ a resistance or, better, a reactive coil in circuit with the arc lamp, so as to change the character of the potential at the lamp terminals, which then becomes less than that of a constant potential, and, in fact, begins to approach, in a measure, constant-current supply. But in the use of a resistance or reactance

in circuit with the lamp, it is, of course, necessary to increase the potential of the line accordingly, so as to give the proper potential to the arc; while both expedients involve a loss of energy. It is found not to be practicable to run alternating arc lamps on circuits much below forty cycles; the common rates of sixty and 125 are well adapted to the case.

The efficiency of the alternating arc as a source of light has been shown by Prof. A. E. Blondel, in a recent paper, to be quite variable. It depends on the length of arc used with the particular carbons employed, and on the diameter of the carbons, as with continuous current. It also depends on the form of the wave of the alternating current. It was found that, with a rectangular wave alternating current, such as may be produced by reversing a continuous current by a commutator, the light given out was as seventy-nine to fifty-nine in the case of sine wave currents. This should follow from the fact that the extinctions, as Blondel pointed out, were instantaneous in the first case, and lasted for about one-quarter of an alternation in the case of the sine wave.

The writer takes occasion to express the opinion that, with very flat-topped waves, or waves approaching closely to rectangular waves, the limit of periodicity would be found far below forty per second, as regards the maintenance of an arc. If the reversal or passage through zero is quick enough, almost any reduction of periodicity would become possible. There are, however, practical considerations which set the limits in such a case.

Soft carbons, or those best suited to readily furnish considerable volatile matter, seem to be best adapted to alternating-current arcs, and they are frequently cored. The color of the light suffers some in consequence.

The distribution of light from an alternating-current arc with vertical carbons, owing to the fact that the chief light source—the positive crater—is on the upper and lower carbon alternately, is both downward and upward. The upward radiation, except in rooms with white walls or ceilings, or with the lamps provided with shades or globes of a strong diffusing power, would be lost except for the employment of deflectors or reflectors immediately above the arc, which catch a fair proportion of the rays and send them downward. The lamp in this case is made focusing, so that the arc will always be kept burning but a short distance below the reflector plate, which is made with a heat-resisting, white enameled surface.

A moment's consideration will show that under no circumstances can an alternating arc give out as much light for a given expenditure of energy as does a continuous-current arc for the same expenditure. The light comes mainly from the positive crater, whose temperature and consequent luminosity is limited by the vaporizing point of carbon. The positive crater from which the current passes to the arc is much larger and much hotter than the negative spot on the opposite carbon receiving current. If, now, there is a rapid interchange or reversal of current and dead points or zeros between the reversals at each alternation, the positive crater has to form anew upon a surface which, while negative, was, on the average, far below crater temperature, having cooled during the time it was negative, and during the zero or period of extinguishment. It results from this that the average temperature of the light-emitting surface of carbon in an alternating arc is below that of the vaporization temperature of carbon, and the emission of light consequently lessened. It is known that the light emitted

from a hot surface as temperature rises, increases far more rapidly than the temperature or total radiation.

The shape of the wave of current has a great influence on the conditions of temperature just pointed out, and the rectangular wave must necessarily approach in its efficiency more nearly that of continuous currents than a peaked wave with longer zeros.

The use of single arcs across alternating constant-potential mains requires only that the lamp mechanism be operated by variations of the current passing the arc. Hence, an electro-magnet in series is used to lift and feed the carbons, or sometimes the expansion of a high-resistance wire, traversed by the lamp current, has been applied for the same purpose, as in the "Kester" lamp. The electro-magnet is open to the objection that its action is so instantaneous as to be liable to provoke chattering at starting, requiring a carefully adjusted check, or dash-pot, to prevent such action, and the magnet armature, or core, may also, unless very carefully arranged, produce by its inevitable vibrations a harsh note audible some distance away. Add this to the hum of the arc itself, and it is easy to see that such a lamp may become intolerable indoors in a quiet room. In the use of a hot wire the objection of chattering at the start is overcome without difficulty, and the wire is noiseless in its action; but it demands that considerable energy be wasted in it, and hitherto the temperature at which the wire must be run to secure sensitiveness of feed or rapid heating and cooling, following variations of current, has been such as to endanger its permanence or cause it to oxidize. If the arc requires twenty-eight to thirty volts, and the regulating wire five to seven volts, it is easy to see that a consider-

able sacrifice has been made for the result attained, particularly as in the use of hot wire over-feeding is liable to take place. The writer obtained, a considerable time ago, a much better result by using the hot-wire principle, but variably shunting it by a set of contacts controlled by a small electro-magnet in series relation, which addition imparted greatly increased sensitiveness, while the slow start given by the hot wire was still secured.

It is well known that in practice an alternating-current arc often starts readily with new carbons, the trouble of chattering appearing when a new arc is to be started with carbons which had before been heated or used. This difference is owing to the fact that in the latter case the high temperature of the arc had driven out the gases and volatile materials which, as present in the ends of the new carbons, facilitate the formation of flame or lower the resistance of the arc at starting. By dipping the ends of the used carbons in a solution of some salt for a moment, the required volatile matter may be furnished to them so that they will start as readily as the new carbons.

The arc in the ordinary alternating-current arc lamp appears to be stable, even when the connection is made across constant-potential mains without resistance or reactance in the branch as a check upon the current. Therefore, nearly all the energy may be thus delivered to the arc itself without deduction. This fact tends to neutralize the lower efficiency of light production in the alternating arc, since the continuous-current arc on constant potentials involves a dead resistance loss. Any comparison, then, must, for practical purposes, consider the total energy used in the branch in which the lamp exists, and the light produced or emitted in directions permitting utilization.

While the alternating arc, run from constant potentials, is feasible, the difficulty of chattering and large variations of current at starting results from the arrangement, and any sudden fall of potential may cause a momentary extinguishment. Particularly is this the case when the arc is of the "inclosed", long-burning type. In such case, on account of the greater length of the arc, it is peculiarly sensitive to influences which would affect but slightly the ordinary open-air arc. With the open-air arc a comprehensive set of tests made under the writer's supervision disclosed the fact that various makes of carbon gave widely different results. It was found that the length of arc or separation of the carbons for a given potential was, under equivalent conditions, quite variable, and the curious fact was noted that with some makes of carbon the variation of arc length with variations in the potential of the circuit supplying the lamp were much less than with certain other makes. Some gave excessive variation of arc length with moderate variations of potential at the arc, while others gave only moderate variations of arc length for considerable variation of potential at the arc. Of course, the latter are far the most desirable carbons for practical use. The results in each case were plotted as a curve, and comparison and superposition of the curves showed the superiority of one or another brand. The curves showed also the arc length for each kind of carbons for a given potential across the arc, which it was important to know in selecting carbons best adapted for alternating-current work. The carbon which gave the longest arc at the lowest potential, and one which did not vary its length as much or more than that obtained with other carbons for certain variations of potential, would practically be preferred, other things

being equal. It is too early to predict what part the "inclosed" alternating arc may play in the future art of arc lighting, but it probably will find a considerable application.

When an alternating arc is run with a considerable dead resistance in series with it, or when a reactance coil is in series, or when it is fed from the secondary of a leakage transformer, taking the whole current thereof, the condition approaches, though in cases only imperfectly, the running of the lamp on approximately constant current. In reality, the condition is intermediate between constant-current and constant-potential working. In such a case the regulation of the lamp may be by a series magnet, or a shunt magnet, or by a combination of both. In fact, there is no real utility in generating a constant current of alternating character for working a single lamp. The utility of the "intermediate" working, just alluded to, is in the lessened liability to rupture of arc, lessened chattering at starting, and avoidance of excessive flux of current if the carbons, by accident, come together. The condition is one decidedly useful in the case of the "inclosed arc" of alternating type, and it is doubtful if such arcs can be run, except under conditions like those here called "intermediate". For saving energy a reactance or reactive coil in the lamp circuit is preferable to a dead resistance, and is relatively more effective.

It may be well to add to the present paper, which has grown to unexpected length, a statement concerning the results arrived at by innumerable tests of the different types of arcs and arc lamps under conditions resembling those of practice, with a view of ascertaining their lighting values. These tests have been embodied in comprehensive reports by Mr. Jesse

Coates, of the testing department of the General Electric Company, at Lynn, and the tabulated results might easily furnish material for a lengthy discussion. They embody complete series of measurements of candle-power in various directions, and curves of the same for each kind of arc or condition of surrounding globe, together with mean spherical and estimated useful illuminating intensities. The methods of measurement can not be detailed here, but are such as, in the writer's judgment, can be relied upon to give comparative figures. Moreover, the mean of many observations is, in each case, taken for comparison and plotting of curves.

The purpose here shall be to state, in a general way, some of the results obtained.

It is well known that the larger the arc, or the larger the current in it with a normal voltage, the more efficient is the light production. The energy is more effectively converted into luminous waves, so that the watts per candle would naturally be less with a twenty-ampere arc at forty-eight volts than with ten amperes flowing. Measurement shows that where, with continuous current, the same brand of hard carbons is used of diameters varying approximately with the current strength, naked arcs, with ten amperes and forty-eight volts, may take for each mean spherical candle-power 1.2 watts, while arcs of seven amperes and forty-eight volts require 1.4 watts.

The use of a cored upper carbon appears to raise the efficiency to a moderate extent, probably because the arc may be maintained at a voltage somewhat less, as at forty-two or forty-four volts. The use of a clear globe surrounding the arc loses ten to twelve per cent of the light, while alabaster and opal globes lose from forty-five to sixty-five, according to their

thickness and the specific absorptive power of the glass. Naturally, since an inclosed arc, consuming approximately the same energy in watts at the arc as a ten-ampere open arc, will have a current of only about seven and one-half amperes, the efficiency would be expected to be less. Measurements show, after a run of 102 hours, and per each mean spherical candle-power of a four and three-quarter-ampere, inclosed, continuous-current arc with clear inner and no outer globe (one-half-inch carbons), an expenditure of 1.94 watts at the arc. If the energy expended in the lamp branch be taken as the true expenditure, that lost in resistance is added to that of the arc, and the watts per candle increased accordingly. A similar loss is, of course, experienced with naked or open arcs on constant potentials, owing to resistance being used in series. The result given above, or 1.94 watts per candle, is at the end of a long run of 102 hours, but with a clear inner globe. Inclosed arc lamps with clear inner and clear outer globes are not satisfactory, and, in fact, for good results of uniformity and diffusion, a slightly opal inner globe is needed. Those now known as "alabaster" are well suited to the purpose. When these are used, the watts at the arc per mean spherical candle-power will, at the first part of a run, range about two watts, increasing seriously only towards the very end of the run. While it may seem that the watts per candle are higher than might be expected, yet it must be borne in mind that, in all inclosed arcs, the current is relatively small and the potential high for a given expenditure of energy, and this acts in a double way to lower the efficiency, as not only the crater emitting light is smaller, but a large part of the energy goes to sustain the arc flame, which is long, while, also, the absorption of light by

the surrounding glass is not to be neglected. No construction of lamp, regulation or adjustment thereof can get rid of the inherent properties here pointed out. Nevertheless, it is true that the character of the light, both of the open or exposed arc, and of the inclosed arc, is such as to make it very desirable as a substitute for daylight and for many cases of use. The fact that the light is shed mainly downward by continuous-current arcs results virtually in an addition to the efficiency and economy of the light; thus, if the light emitted downward be considered as alone useful, the expenditure per mean useful candle would, with naked arcs, fall to about one-half a watt, and with inclosed arcs, to from one to one and one-half watts at the arc.

With alternating arcs the conditions are different, since the light is sent up and down equally. By a reflector placed above the arc, a considerable fraction of the light which would often be lost upward is sent downward to increase the effectiveness; thus, a sixteen-ampere, twenty-five-volt, naked alternating-current arc used, per mean spherical candle, 1.49 watts, or for mean useful below the horizontal, 1.12 watts, which was reduced to .8 to .9 watt, when a porcelain reflector above the arc was used. For the same causes that necessarily reduce the efficiency of an inclosed continuous-current arc as compared with the uninclosed, the efficiency of an inclosed alternating arc falls below that of the open arc with similar currents. The watts at arc per candle will be found, per mean spherical candle, to be, under the best conditions, about two watts, increasing toward the end of the run, owing to obscuration of the inner globe and other causes. No reflector or deflector can be used with much effect with the inclosed arc, so that the mean

useful is but little different from the mean spherical candle-power.

The apparent advantage in economy of the continuous-current inclosed arc over that with alternating currents is in large measure neutralized by the fact of the former requiring a dead resistance in circuit to give stability to the current, while the latter can be run without it, or, at most, with a reactive coil which wastes but little energy.

Still it must be confessed at the end that the luminous yield is but little better than that obtained in incandescent lighting. After all, it may be that the whiteness of the light and the daylight effect obtained may be a sufficient reason for the large introduction of inclosed arcs, now that the frequent trimming and attention to the lamp is not needed. Indeed, it may also appear that all the varieties of arc lighting which have grown into importance within the past few years have their own fields of usefulness, and that, therefore, the work spent in developing them has not been labor in vain.

It should be said, in conclusion, that the figures given above and expressing the watts per mean spherical candle, while strictly comparative so far as a study of arc lights alone is concerned, might vary somewhat if the object had been to compare arc and incandescent lights, owing to the difference in color of light, though the variation would not in any case be great.

A MEMBER: I move that the paper be accepted, and that the association return a vote of thanks to Professor Thomson for his able paper.

Carried.

THE PRESIDENT: Professor Thomson, I wish to convey to you the thanks of the association for your very able and instructive paper.

THE PRESIDENT: The next item on the programme is a paper by Mr. T. Commerford Martin, on "The Daylight Work of Central Stations."

MR. MARTIN: My understanding of the printing of a paper is that it is for the suppression of amateur elocutionary efforts, and, as my paper is in type, I do not think it is at all necessary that I should inflict it upon you by slowly and laboriously wading through its successive pages. If there is any question that any gentleman wishes to bring up in connection with any remarks in the paper, or any criticism that anyone wishes to make. I shall be very glad to give attention to it; otherwise, I think perhaps we have more important and interesting matters outside.

THE PRESIDENT: In other words, Mr. Martin, you suggest that your paper be read by title.

(For full text of Mr. Martin's paper, see appendix, page 423.)

MR. L. B. MARKS: Mr. President, would it be in order to take up the discussion of Mr. Martin's paper, and also the discussion of Professor Elihu Thomson's very able paper, to-morrow morning? I should like to say a few words in relation to Professor Thomson's paper, and I know that the association wants to get out now, but I think that perhaps we shall have a little time to-morrow morning.

THE PRESIDENT: We will certainly afford time for the discussion if it is at all possible to do so. Fortunately, the papers to-morrow morning do not promise to take up an unusual length of time, and if we convene promptly on time, I have no doubt that we shall have time at our disposal for the discussion of various matters that will be relegated for consideration until to-morrow. If that is your pleasure, after a vote of thanks has been moved to Mr. Martin, I will declare the session adjourned.

MR. INSULL: I move that the thanks of the association be tendered Mr. Martin for the presentation of his paper, and that any discussion be postponed until after the papers are read to-morrow morning. I say "after," because I know that Mr. Martin has an engagement in the morning, and he may be able to get here by eleven o'clock.

The president put the question and it was determined in the affirmative.

THE PRESIDENT: Mr. Martin, you are tendered the thanks of the association.

On motion of Mr. Ayer, duly seconded, an adjournment was taken until 10.30 a. m.

# NIAGARA POWER

## *Special Evening Session*

LECTURE BY L. B. STILLWELL, E. E.

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Sixty-eight years ago, M. Guizot, Professor of History in the Faculty of Literature, at Paris, delivered a remarkable course of lectures upon the general history of the civilization of modern Europe. In the introduction to these lectures he divided the facts and forces that operate to advance civilization into two classes: first, those that help to shape the history of a nation by influencing society as a whole—"its institutions, its commerce, its industries, its wars, the various details of its government," and, second, "certain facts which, properly speaking, cannot be called social—individual facts, which rather concern the human intellect than public life; such are religious doctrines, philosophical opinions, literature, the sciences and arts." "These latter forces," he says, "seem to offer themselves to individual man for his improvement, instruction or amusement, and to be directed rather to his intellectual melioration and pleasure than to his social condition." "Yet, still," he continues, "how often do these facts come before us; how often are we compelled to consider them as influencing civilization. In all times, in all countries, it has been the boast of religion that it has civilized the people among whom it has dwelt. Literature, the arts and sciences have put in their claim for a share of this glory, and mankind has been ready to laud and honor them whenever it has felt that this praise was fairly their due."

I invite your attention to this quotation, not because the facts and forces referred to were, at the time sketched, in anything but their true relative proportions, not because Guizot's perspective was incorrect for the year 1829, but because the perspective of his picture was at that time true, and because since that time one of the forces to which he refers—then in the background—has grown into the very foreground of every true picture of the forces contributing to modern civilization that can be painted to-day. A few years after these lectures were delivered, the first steam locomotives in England and America were put into operation. In 1831, Michael Faraday observed that a copper disc revolved in the field of a magnet was traversed by an electric current, and now, within the short span of a scriptural lifetime—three score years and ten—engineering science, by steam and electricity utilizing natural forces practically unobserved throughout all the long centuries preceding, has affected a greater change in man's social condition, and has, perhaps, done more to promote civilization than any other civilizing force. In a history of civilization, what a place must now be given to the art of steam engineering; the applied science of thermo-dynamics; not as "rather concerning the human intellect than public life;" not as "offered to individual man for his improvement, instruction, or amusement;" not as "directed rather to his intellectual melioration and pleasure than to his social condition;" but, on the contrary, as profoundly affecting social conditions by cheapening the necessities and comforts of life, by reducing the hours of labor and by imparting an almost incalculable stimulus to intellectual activity in every direction. And what a place must now be accorded to applied electric science; covering the

earth with lines of instant communication, bringing all lands into touch; lighting the dark places in our cities; doubling areas available for suburban residence; separating the very molecules of matter into their constituents, or forming new compounds; and now, beginning to turn the wheels of industry in hundreds of factories and mills.

It is unnecessary to demonstrate to this audience that well-distributed acquisition of material wealth is desirable, and tends to advance civilization. It will be conceded at once that a wise and not wasteful utilization of natural forces, cheapening the cost of power for a community, is praiseworthy. We all believe that there is in the universe a certain fixed quantity of matter, which we are powerless to increase or decrease, and we accept the doctrine, first fully enunciated by Helmholtz, that Nature provides also a fixed quantity of energy, to which we can add nothing and from which we can take nothing away.

A man, considered as an engine and compared with the vast supplies of energy available in coal and falling water, is capable of but an insignificant amount of work. It has been calculated that a very strong man, exerting himself very violently, can, for a few minutes, work at a rate approximating one-fifth of a horse power; but we have only to remember that one-fifth of a horse power means 6,600 foot-pounds per minute, and that this is equivalent to lifting 110 pounds one foot every second, to perceive that the calculation does not apply to the average man performing continuous work by the hour. Considering work continued for ten hours per day, I think it is safe to say that the average output of fifty strong laboring men, working steadily and faithfully, would not exceed one horse power, and it is probably no exaggeration to

say that the power of Niagara exceeds the physical power that the whole human race is capable of continuously exerting.

Niagara is a great solar engine. You all understand the cycle. Water raised by the sun from sea and lake and river is precipitated to the earth by changes of temperature, finds its way into the Great Lakes, and thence, by the Niagara River, to the rapids above the falls, more than 200 feet above the level of the water in the gorge immediately below the cataract. To raise a pound of water from the river below the gorge to the head of the rapids, a force of one pound must be exerted through a distance of, say, 200 feet. Therefore, every pound of water at the upper end of the rapids represents 200 foot-pounds of energy, which are given up in falling to the lower level. The rate of flow exceeds 7,000 tons of water per second, and the total horse power is estimated (by the United States census of 1880) to exceed 5,800,000 horse power. That is an enormous amount of power. Let us see how much coal we should have to burn to develop as much. A committee of the National Electric Light Association several years ago made a systematic effort to ascertain the economy in the consumption of coal obtained in electric light stations throughout the United States. The final report of this committee is not before me, but the preliminary report submitted at the convention in St. Louis, March 1st, 1893, showed that the average consumption of coal in these stations per horse power hour, measured, as I understand, by electrical measuring instruments on the switchboard, slightly exceeded six pounds. At this rate, it would be necessary to burn more than 130,000,000 tons of coal per annum to develop power equal to that of the Niagara River from the upper

limit of the rapids to the gorge below the falls. This would be substantially one-third the coal product of the world, and would materially exceed the entire amount of coal now used for power purposes. With the best of modern steam plants, the consumption of coal would still exceed the entire annual output of the anthracite coal fields of Pennsylvania. Making all necessary allowance for loss in an hydraulic plant, the power of Niagara Falls, if it could be utilized as a whole, would supply more than 3,000,000 arc lamps of 2,000 nominal candle power each. An idea of what that number means may be obtained by imagining a row of arc lamps on either side of a railway track extending from New York to San Francisco. Were the number named available, 2,000-candle-power lamps might be located on either side of the track at intervals of twelve feet throughout the entire distance. Expressed in terms of sixteen-candle-power incandescent lamps, there is sufficient power to drive 600 generators like those now installed in the power house of the Niagara Falls Power Company, each of which supplies energy equal to that required by about 75,000 fifty-watt lamps; or, to put it still another way, the power of Niagara, if used for the refining of copper by electrolysis, would deposit more than 2,000 net tons per hour.

There is an important difference between using the energy of coal and utilizing the energy of water powers for power purposes. Coal once burned cannot be used again. Water powers, on the other hand, are solar engines perennially renewed. We may utilize the energy of Niagara to-day without subtracting a single horse power from that which Nature intended, not only for our age, but for future ages. The thought, therefore, immediately suggests itself that we

should, so far as possible, utilize our water powers in the mechanic arts, burning coal only for our protection from cold, for the preparation of food, for necessary metallurgical purposes, etc. If this be impracticable, we should at least see to it that our utilization of the energy of coal does not involve undue waste.

Of course, not all of the power of Niagara can be utilized. Aside from æsthetic considerations, which will, perhaps, for all time prevent the utilization of a sufficient amount to impair the beauty of the falls, and considering the subject simply as an engineering problem, large deductions from the figures above named must be made, to cover the difference between the total and the effective head, this difference representing the fall in canals and tunnels conveying water to and from the wheels. I suppose that it would be possible to deliver about 4,000,000 horse power to the turbines, and of this amount the turbines would deliver about 3,200,000 horse power at their shafts.

At this point—the shaft of the turbine—engineering science for a long time halted. Water wheels appear to have been used at least 2,000, and probably 4,000, years ago, though not extensively. Every water wheel necessarily had a shaft upon which it was supported and about which the blades revolved. The problem was, how might the power be conveyed from the shaft to a point where it could conveniently be made to do work. Naturally enough, men first used for this purpose something that they could see and handle and readily comprehend. They used wooden shafts, then ropes and belts. Then someone thought of using a liquid, and the science of hydraulics began. Still later, somebody suggested using a gas—compressed air—and pneumatic transmission attempted to solve the problem.

When the officers and directors of the Cataract Construction Company came to decide what methods of developing and distributing the power of Niagara should be adopted, they faced a problem of transcendent importance. It involved far more than the mere capital to be invested; it involved, in no small degree, the future development, the prosperity, of a territory bounded by a circle having for its radius the utmost distance to which the future advancement of engineering science might make it possible to transmit power; and the decision of the company carrying out to a conclusion a project inaugurated on so vast a scale, occupying so conspicuous a position in the eyes of the scientific and engineering world, must inevitably exert a powerful influence upon the great world problem of the economical utilization of our supplies of natural energy. To utilize and distribute over the widest range, with the least waste, with the greatest certainty, and in form adapted to the widest variety of applications,—these were the conditions to be met. To enumerate them now is to suggest to all our minds, with absolute certainty, electricity, the Proteus of engineering science as it exists to-day; but it must be remembered that when those who inaugurated and have thus far carried out the project began their study of the problem, the possibilities of electricity had not been demonstrated and recognized as they are to-day. At that time, the relative advantages and the limitations of water, air, rope transmission and electricity were less evident than now, and it was necessary to examine with great care, and weigh with accurate judgment, the merits and defects of many different plans. This the company proceeded to do with remarkable patience, thoroughness and ability, inaugurating a competition which many of the

most prominent engineers and manufacturing firms of Europe and America were invited to enter, and offering prizes for the best solution of the problem. The question was in no sense begged at the outstart. The company did not select electricity because it was the newest agent for transmitting power, nor because the general public was (as it still is) disposed to assume that electricity is necessarily the agent best adapted to the solution of every engineering problem. They arrived at their decision to use electricity only after several years of investigation, in which, practically without regard to cost, they endeavored to secure the best of engineering talent, and in which they allowed no prejudice and no difficulty to narrow or limit their cosmopolitan search for the best solution.

Let us consider very briefly some of the limitations to which our various methods of transmitting power are subject. For obvious reasons, transmission by shafts, ropes and belts is effective and efficient only over comparatively moderate distances. A shaft, for instance, even a hollow shaft, if strong, is necessarily heavy. It must be supported and carefully aligned. To effect a change in the direction of transmission, special devices, such as gears and pulleys, must be used. All this means loss of efficiency at every step, and the economical limit is soon reached. In the case of transmission by ropes or cables, also, loss of efficiency results from the necessity of supporting the weight, and sharp turns are difficult to make and imply heavy losses. Subdivision by shafts or cables can be mechanically effected only by the interposition of pulleys, gears and similar devices, all of which consume energy, and therefore imply waste.

Hydraulic transmission is also limited to comparatively short distances. Under certain conditions, and

for distances not exceeding two or three miles, it is used with good results. The municipality of Geneva, Switzerland, under the able direction of Colonel Theodore Turrettini, foreign consulting engineer of the Cataract Construction Company, has established an hydraulic plant for the distribution of power throughout that city, which has been splendidly successful, and is worthy of most careful study. Colonel Turrettini and the municipality of Geneva, however, recognize the superiority of electric transmission over distances exceeding a very few miles, and they have more recently constructed a second power plant some four miles further down the Rhone; in this case using electricity to transmit and distribute the power.

Some of the causes that limit the distance to which power can be economically transmitted by water will readily occur to you. For example, the amount of power transmitted through a pipe by water under pressure is proportional to two things: the quantity of water that flows through the pipe in a given time, and the head or pressure. Friction increases with pressure, and also with an increase in the length of the pipe. Then, the efficiency of water motors, particularly those of comparatively small output, is low as compared with that of electric motors. Again, the chance of water freezing in the pipes must be considered; and a limitation, not frequently encountered in practice, but still worthy of note, results from the fact that water, unlike electricity, has weight. If we were to undertake to carry a pipe line filled with water over some of the mountain ranges now crossed by electric conductors, we should have a pressure in the pipe, at certain points, of not less than 1,500 pounds per square inch, due to the greater elevation of other parts of the line.

The limitations of pneumatic transmission have not been accurately determined, and it is probably possible to obtain better results by this means than have as yet been realized in practice. Air compressors, however, have been made for many years, and as compared with electric generators are much less efficient. To compress a gas, means necessarily to develop heat, and this, so far as our purpose of transmitting power is concerned, involves loss; and while it seems probable that by using very high pressures in pipes of comparatively small diameter, the cost of a system transmitting by compressed air may be much reduced as compared with present practice, there are serious difficulties to overcome, and up to the present time no satisfactory method of surmounting these difficulties has been demonstrated.

The fourth solution of the problem of transmission is by electricity; that is, by ether under unbalanced pressure. Note, if you please, the interesting sequence of the several solutions of this problem of transmitting power: First, a solid; then, a liquid; then, a gas; and, finally, something (if I may use the expression) more volatile, more subtle, even than a gas; something which, in itself, we can neither touch, taste, smell, hear, nor see; something which we know only by its effects; something so elusive that for centuries the world did not know that it existed. Is it not significant of the progress of engineering science that it should thus have advanced from those agents directly perceptible to our senses to one which our physical senses cannot perceive—from the material to the immaterial?

And now, what is ether? What is electricity? And how is power transmitted by electricity? These are questions that the science of the present day can-

not fully and satisfactorily answer. But we are not totally ignorant of the nature and characteristics of this agent which we are using with such confidence and assurance of results, and it is not difficult to form in our minds a rough conception, useful as a working hypothesis, though not susceptible of proof, and very properly subject to criticism from various points of view. We know from optics that there is a medium which is not a solid, not a liquid, and not a gas. We may exhaust the air from a glass vessel and light will still pass through it. Air, therefore, is not the medium by means of which light is transmitted. Evidently, there is something still in the glass vessel, which serves to convey the ray of light. We know, also, that the space between the earth and the sun is not filled with air, and yet it is traversed by light. We assume, therefore, that the interplanetary spaces are filled with this same something, and, for convenience, we call it ether, and proceed to study its phenomena. The science of optics, which deals with the propagation of light through this medium, is so well established by observed facts, and by general theories which explain and interconnect these facts, that practically nothing within the range of human knowledge is more certain than that something which we call ether does exist and that it pervades all space and all matter. In 1888, the German physicist, Hertz, proved beyond the shadow of a doubt that electric and magnetic phenomena have to do with this same medium.

Electricity is defined as ether in a state of strain, or, more properly speaking, in a state of unbalanced strain—this strain manifesting itself along the conductors of an electric circuit connected at one end to a dynamo in action and at the other end to a lamp,

motor, or other translating device. Professor Lodge advises us to conceive of an electric conductor as a hole through the ether. The static balance of the ether being relieved or unbalanced along the surface of the conductor, and the strains to which our world of ether is subject (somewhat as water at the bottom of the sea is under pressure) being unbalanced along the line of the circuit, the ether transmits along the surface of the conductor the strain or pressure imparted to it by the dynamo. We need not pause to consider whether the strain is transmitted by the ether within the copper conductor or along its surface, but we may imagine that following the path of the conductor from the dynamo to the motor and back again from the motor to the dynamo, a loop or chain of ether transmits a stress or strain from the dynamo to the motor, somewhat as a belt conveys power from a driving to a driven pulley.

In the telegraph, and more recently in the telephone, we have become familiar with some of the characteristics of electric transmission; notably, the fact that it is practically instantaneous in its action. We press a key in America, and the mind of an operator in England almost instantly has our thought. The mechanical movement of the transmitting instrument here causes a mechanical movement of part of the recording instrument there. It is as if they were connected by a rigid bar less compressible than steel, yet weighing nothing.

We are less familiar with the fact that electricity is strong, but observation of thousands of street railway cars driven at high speeds and up heavy grades, and of motors operating heavy machinery in mills and factories, is teaching us this also. As a matter of fact, the power transmitted through a copper con-

ductor of given section, at the potential now being employed by the Niagara Falls Power Company in transmitting power to Buffalo (between 10,000 and 11,000 volts), is sufficient to break many steel cables of equal section moving ten miles per hour and attempting to transmit equal power. At 10,000 volts, a single-phase circuit consisting of a copper conductor one inch in section and carrying 1,000 amperes transmits more than thirteen thousand horse power. The strain upon a cable transmitting this amount of power mechanically and moving ten miles per hour, would exceed one million pounds—enough to break eight steel cables one inch in section and having the high ultimate tensile strength of 125,000 pounds per square inch. In three-phase transmission, such as is used between Niagara and Buffalo, the results in this respect are still more remarkable, but to consider three conductors makes our comparison with a steel cable less evident.

Power transmitted by electricity is delivered in a form adapted to a remarkable variety of uses, and, as compared with power transmitted by any other system, possesses important advantages. Supplied to a motor, it performs mechanical work at efficiencies ranging from sixty to ninety-five per cent, depending upon the size of the motor. Delivered to an arc lamp, it produces from 1,500 to 2,000 actual candle power per horse power. Used to supply incandescent lamps, it produces light agreeable in quality, possessing substantial advantages over other forms of illumination, and developing from 200 to 250 candle power per horse power. Conveyed to the terminals of the electric furnace, it produces, by synthetic process, various materials new in the arts and of great value, or, traversing the electrolyte of the chemist, it tears apart the very

molecules of which matter is composed and segregates their constituent elements. Unlike shafts, belts and cables, it can be indefinitely subdivided without material loss. It can readily turn corners. It is transmitted vertically with as much ease as horizontally. Unlike water, it never freezes, and, unlike compressed air, it can be delivered from the generating machinery and transmitted many miles at very high efficiency.

And now, how is the Niagara Falls Power Company proceeding to develop Niagara power under the grants which it has received from the State of New York and the Province of Ontario? The plans have been so often and so fully described that I do not propose to consider them in detail to-night. In general, however, I desire to invite your attention to certain facts connected with the work, and to certain features of the plans and the methods of construction adopted, which demonstrate, I think, that the Niagara Falls Power Company thoroughly understands the magnitude and far-reaching consequences of its project; that it is carrying out the project with remarkable skill and courage, and with an evident desire to build, not only for the present, but for the future, and that it aims, not only to secure a fair return upon the capital invested, but to insure to the entire country within the rapidly receding horizon of practical power transmission the advantages that should result from the possession of this wonderful gift of nature.

## ORDER OF BUSINESS

THURSDAY, June 10th, 1897.

FIFTH SESSION, 10.30 A. M.

1. Paper—"The Polyphase Motor." By BENJ. F. LAMME.

SIXTH SESSION, 2.30 P. M.

1. Paper—"Frequency Transformation." By LIEUTENANT F. JARVIS PATTEN.
2. Paper—"Rotaries for Transforming Alternating into Direct Current." By CHARLES F. SCOTT.
3. Report—Committee on Standard Candle Power of Incandescent Lamps. LOUIS BELL, Chairman.
4. Topic—"Freight Classification of Electrical Apparatus and Goods."
5. Executive Session.

## FIFTH SESSION

President Nicholls called the meeting to order at 10.30 a. m., and introduced Mr. Benjamin G. Lamme, of Pittsburg, Pennsylvania, who read his paper on "The Polyphase Motor."

# THE POLYPHASE MOTOR.

The polyphase motor is usually treated from the theoretical standpoint, and the results obtained are of interest mainly to designers and investigators. Such treatment has been principally of a mathematical nature, the object being to show how the various characteristics of the motor may be predetermined. This is what the designer requires, but it gives very little information to the practical man, who uses the motor. In the following treatment of the subject, the general operation of the motor will be explained in a non-mathematical way by the use of diagrams which illustrate its characteristics under different conditions. Only the non-synchronous type of motors will be considered, and no distinction is made between two and three-phase motors, for, if properly designed, they are practically alike in operation.

It is necessary to understand the characteristics of the polyphase motor in order to consider properly its application to the different classes of work to be met with in practice. These characteristics can be represented in the most intelligible manner by means of curves, which represent the relations between the speed, torque or turning effort, horse power expended and developed, amperes, etc. The speed-torque curve, which represents the speed in terms of the torque, is the most important one, as upon this depends the adaptability of the motor to the various kinds of work. The starting conditions also depend upon the speed-torque characteristics. The other curves that

are of importance in practice are the current, efficiency and power factor. As these are dependent, to some extent, upon the speed-torque curve, that should be considered first. Before treating of its characteristics, a short description of the motor itself will be given.

The polyphase motor, like a direct-current motor, consists primarily of two parts, one stationary and the other rotating, each of which carries windings. The inside bore, or face, of the stationary is generally slotted, and carries windings that resemble those of an ordinary direct-current armature without the commutator. The rotating part is also slotted on its outside face, and there are windings in the slots. Both cores or bodies are built up of thin iron or steel plates. The general arrangement is shown in Figure 1. One of these windings, generally on the stationary part, receives current from a two or three-phase supply circuit. The coils of this winding, although distributed symmetrically over the entire face of the core, are really connected to form distinct groups which overlap each other. These windings form the two or three circuits in the motor. When alternating electromotive forces are applied to these circuits, currents will flow which set up magnetic fields in the motor. These alternating fields in turn generate electromotive forces in the windings. Part of the current flowing in the windings represents energy expended usefully, or in heating, and part serves merely as magnetizing current. The latter, like the magnetizing current of a direct-current machine, is dependent upon the dimensions of the magnetic circuit and upon the magnetic density in the various parts. Even when running with no load the magnetizing current is required.

The second part of the motor, generally the rotating, receives no current from the supply circuit.

The magnetic fields set up by the first set of windings pass through the second windings, and, under certain conditions, generate electromotive forces in them. If the second windings are arranged to form closed circuits, currents will flow in them. These

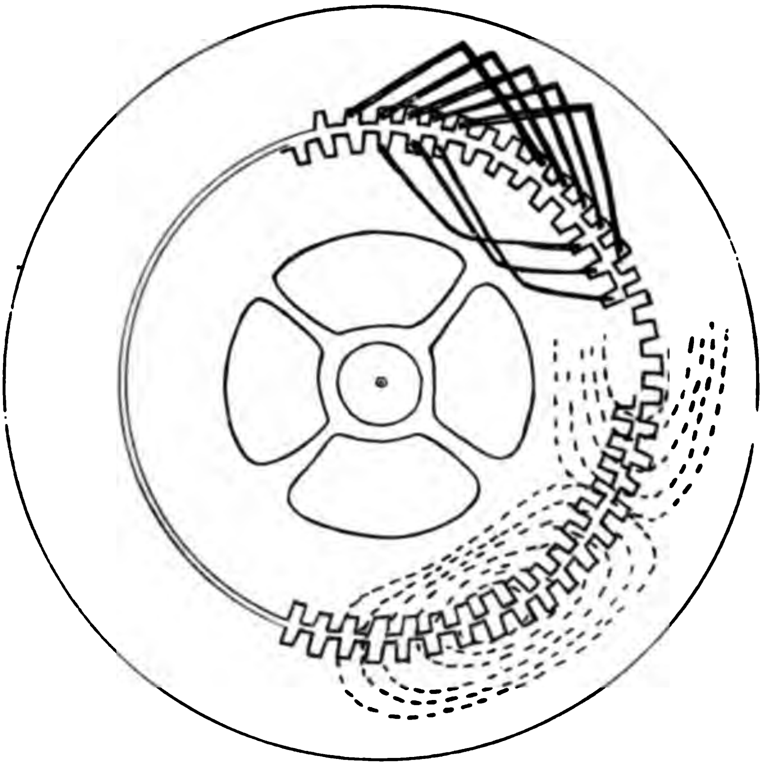


FIG. 1.

currents are entirely separate from those of the supply circuits.

When running, the motor has a maximum speed that is approximately equal to the alternations of the supply circuit divided by the number of motor poles. This is the no-load speed. As the motor is loaded,

the speed falls off almost in proportion to the load. The drop in speed is sometimes called the "slip." This is usually expressed as a per cent of the maximum speed. If, for instance, a motor has a maximum speed of 1,000 revolutions and drops fifty revolutions below this at full load, it then has a slip of five per cent.

With this type of motor, a drop in speed is necessary for developing torque. A fairly simple illustration of this action may be obtained by considering the operation of an alternating-current generator under certain conditions. We will take a type of alternator having a stationary armature and a rotatable field magnet, which can be driven at various speeds. Leads are carried out from the armature to adjustable resistances. To avoid complexity, the armature circuits and the resistances are considered as non-inductive. The field coils are excited by direct current. Figure 2 shows this arrangement. When the field is rotated at a certain speed, with the field coils charged, there is an alternating electromotive force set up in the armature winding. When the armature circuit is closed through a resistance, a current will flow and the armature develops power. The power developed by the armature is slightly less than the power expended on the field shaft, which is proportioned to the product of the speed and the turning or driving effort on the shaft. Consequently, at a given speed, a driving effort is required at the field shaft, corresponding to the power developed by the armature. If the armature current is increased or decreased, the power developed is increased or decreased also, and the driving effort will vary in proportion. Let the field be rotated at one-half the above speed. The armature electromotive force becomes one-half what it was before. Reducing

the resistance in the armature circuit to one-half, the same current as before will flow. The power developed by the armature is now one-half and the speed of the field is one-half, consequently, the driving effort is the same as before. Reducing the speed further, and decreasing the resistance in the armature circuit in proportion, to keep the armature current constant, we find the driving effort on the field remains constant. Finally, reduce the speed so much that the

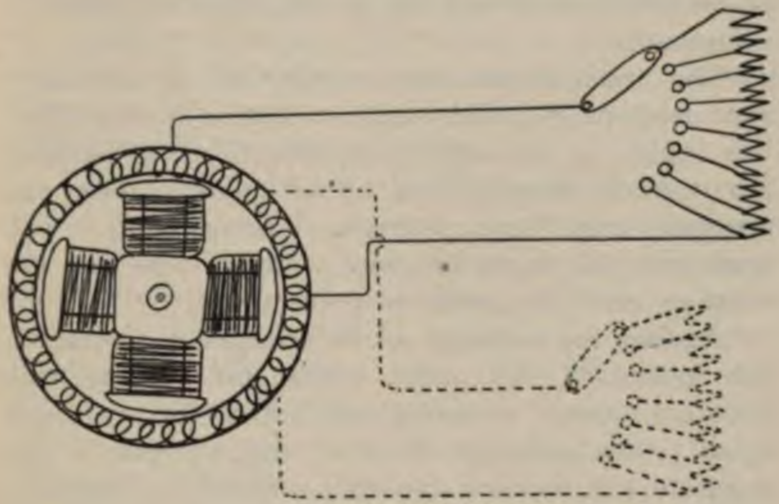


FIG. 2.

external armature resistance is all cut out, and the armature is short-circuited on itself with the same current as before. The same driving effort is required. The field is now rotating very slowly, and the alternations in the armature are very low, being just sufficient to generate the electromotive force required to drive the armature current against the resistance of the windings. Any further reduction in speed will diminish the armature electromotive force, and the

armature current must fall, the power developed will be diminished and the driving effort must also fall in proportion. An increase in speed will increase the armature current, and thus increase the driving effort required.

If but one armature circuit is closed, the power developed will pulsate as the armature current varies, from zero to a maximum value, and the driving effort will also vary. But if the armature has two or more circuits having different phase relations, it may develop power continuously and the driving effort will then be continuous.

The armature has been considered as stationary and developing power while a certain driving effort was applied to the field. According to the well-known law that any force is met by an opposing force, the armature must have a certain resisting effort. The armature really tends to rotate with the field, and the resisting effort is exerted to prevent this.

Assume the armature to be arranged for rotation, but locked, in the above operations. Release the armature, attach a brake, and adjust for a torque equal to the resisting effort of the armature. The armature just remains stationary. Speed up the field, and the armature will speed up also, keeping a certain number of revolutions behind the field. This difference in speed is that required for generating the electromotive force necessary for sending the current through the armature. The alternations in the armature will remain constant for a given armature current, independent of the speed at which the armature is running. If the brake be tightened, the armature must drive more current through its windings to develop the required effort, the armature alternations must increase, and the armature will lag behind its field more than

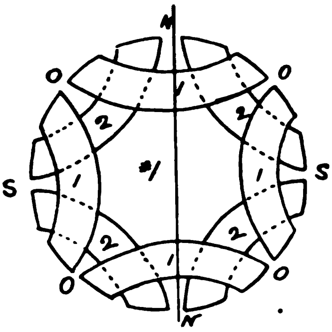
before or the slip is increased. If the brake be loosened, the armature will run nearer the speed of the field. If the field be driven at a constant speed and the brake be released, the armature will run at practically the same speed as the field. If the winding consists of but one closed circuit, the torque developed by the armatures varies periodically, and that developed by the brake will vary also, but to a less extent, as it is steadied by the inertia of the rotating armature. But with two or more circuits having different phase relations, arranged for constant power developed in the armature windings, the torque developed is also constant at all times. Consequently, for constant torque at the brake, there should be two or more phases in the armature windings.

This explanation of the development of torque in the short-circuited armature is merely an attempt to illustrate certain of the actions in the polyphase-motor armature by a comparison with the operations of other apparatus that is, in general, much better understood. We cannot infer, from the above illustration, that an alternating-current generator would run as a motor under the assumed conditions, for, in the above operations, mechanical power is supplied to the field shaft, and mechanical power is delivered by the rotating armature to the brake. There is no true electro-motor action; that is, there is no transformation of electrical power supplied to mechanical power developed.

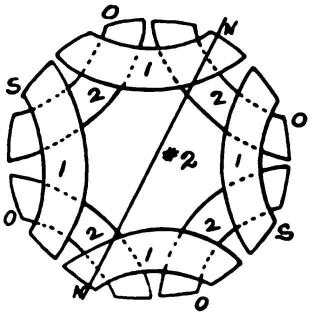
The action of the short-circuited armature of the above generator and that of the polyphase motor are very similar in regard to drop in speed for developing torque. But, instead of the mechanically rotated field magnet, there is a stationary core provided with two or more windings which carry currents having differ-

ent phase relation. These windings are placed progressively around the core, either overlapping or on separate poles. When currents flow in the windings, resultant magnetic poles on fields are formed, which are progressively shifting around the axis of the motor. The closed or short-circuited armature, rotating in this field, develops torque by dropping in speed, in the same way that it developed torque with mechanically rotated field magnets. But electrical power, instead of mechanical, is now supplied to produce the shifting or rotating field, and the conversion from electrical power supplied to the field windings to mechanical power developed by the armature shaft is a transformer action which does not appear in the above illustration. Figure 3 shows diagrammatically the progressively shifting field, with two overlapping windings arranged for two-phase currents. Coils 1–1, etc., form one circuit, while coils 2–2, etc., form the other.

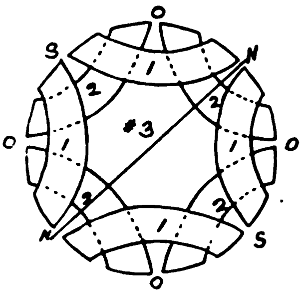
Starting with current in *1* at its maximum value, its magnetizing force must be at its maximum. The current and magnetizing force of circuit *2* are at zero value. Four poles or magnetic fields, alternating N–S–N–S around the core, are formed directly over coils *1*. As the current in *1* begins to decrease, that in *2* rises. We then have the combined magnetizing forces of the two overlapping windings. These two magnetizing forces act together at some points, and oppose at others. The resultant magnetic field shifts to one side of the former position. As the current in *1* gradually falls to zero and *2* rises to its maximum value, the magnetic field shifts around until it is directly over coils *2*. If the current in *1* should next increase in the same direction as before, while *2* diminished, the magnetic poles would shift back again to their former position. But the current in *1*, after



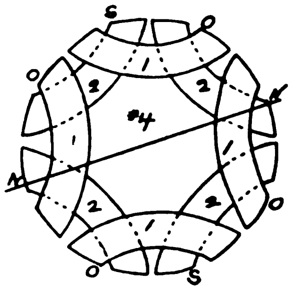

CIRCUIT 1 AT MAXIMUM CURRENT.
CIRCUIT 2 AT ZERO CURRENT.



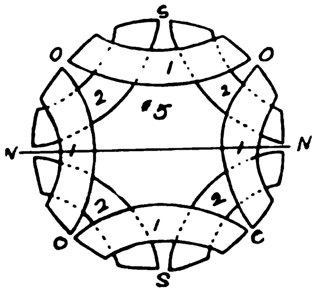

CIRCUIT 1 WITH DECREASING CURRENT.
CIRCUIT 2 WITH INCREASING CURRENT



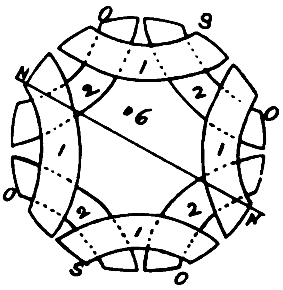

CIRCUIT 1 AT ZERO CURRENT.
CIRCUIT 2 AT MAXIMUM CURRENT.




CIRCUIT 1 INCREASING IN REVERSE DIRECTION.
CIRCUIT 2 DECREASING.




CIRCUIT 1 AT MAXIMUM IN REVERSE DIRECTION.
CIRCUIT 2 AT ZERO.




CIRCUIT 1 DECREASING.
CIRCUIT 2 INCREASING IN REVERSE DIRECTION.

FIG. 3.

reaching zero value, rises in the opposite direction, while *2* falls. This shifts the resultant poles forward instead of backward, and they gradually shift ahead until they are again directly over coils *1*. But the *N* poles have shifted around until they occupy the former position of the *S* poles. Thus, with the current in *1* passing from a maximum in one direction to a maximum in the opposite, the poles have shifted forward the width of one polar space. Current *2* next rises in a reversed direction, and the poles shift forward until they are over coils *2*, with the maximum current in *2*.

In the diagrams, Nos. 1, 2, 3, etc., show the positions of the shifting field under certain conditions of current in the two circuits. In No. 2, the position shown is an arbitrary one, for it depends upon the relative values of the currents in the two circuits. With the two currents equal, the position would be half-way between Nos. 1 and 2.

These diagrams show that the magnetic field due to the two-phase currents in properly arranged windings shifts progressively around the axis, just as if the field were rotated mechanically.

The stationary core, in the above description, is in practice, placed outside the revolving armature instead of inside, but this in no wise affects the conditions of operations as explained above.

In polyphase motors, the part that resembles the field in the above description, and which receives the current from the line, is usually called the primary, on account of its electrical resemblance to the primary of a transformer. The equivalent of the armature in the preceding description is called the secondary. If the alterations of the supply circuit are constant, the reversals of the current in the field or primary will occur at a uniform rate, and the magnetic field will

shift around its centre at a definite speed, depending upon the rate of alternation of the supply circuit and the number of poles in each circuit of the motor. If the armature or secondary rotates at the same speed as the field shifts, there will be no reversals or alternations in its magnetism, and there will be no currents and, consequently, no torque. If a load is thrown on, the speed will drop, and the resultant alternations in the secondary will generate electromotive forces which will drive currents through the windings, and thus develop torque. The speed will

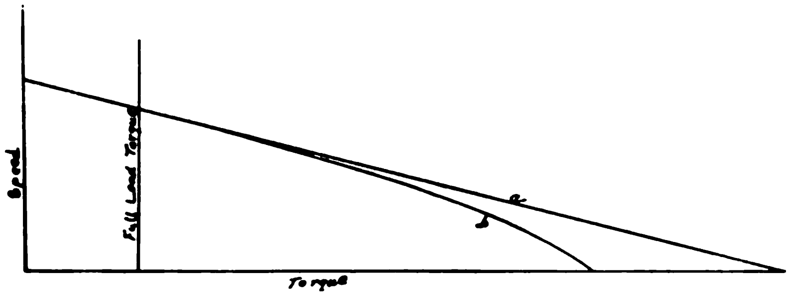



FIG. 4.

fall, and the secondary electromotive forces will increase until a torque is developed sufficient for the load carried. Increasing the load on the motor, the speed should fall and the torque increase until zero speed is reached. The speed-torque curve would then be of the form shown in Figure 4, curve *a*. But the shape of this curve is modified to a great extent in actual motors by certain effects which cannot be entirely eliminated.

In the case of the revolving field, the magnetization was supposed to remain constant under different

conditions. But in the motor primary, the magnetism of the primary is not constant under all conditions, and it does not all pass through the secondary circuits. The primary windings necessarily have some resistance, and a certain electromotive force is required to drive the primary current through the windings. With a constant applied electromotive force, the primary counter-electromotive force will diminish as the drop in primary resistance increases, and the magnetic field required will diminish also. To develop the required secondary electromotive force for driving the secondary current through the windings, the speed must drop more than shown by curve *a* in Figure 4. This gives a speed-torque curve as shown by curve *b* in Figure 4. Instead of being a straight line, it is somewhat curved.

But there is a still more important effect in the motor. The primary and secondary currents, and their consequent magnetizing forces, are opposed to each other. The result is that part of the primary magnetism threads across between the primary and secondary windings without passing into the secondary. Thus, the electromotive force of the secondary is reduced, or, for a required secondary electromotive force, the secondary alternations must be increased. This means a further drop in speed. The secondary currents also tend to form local magnetic fields around their own coils. These local fields are alternating, and set up electromotive forces in the secondary circuits. In consequence, the electromotive forces generated by the magnetism from the primary have to drive currents, not only against the resistance of the windings, but also against these local electromotive forces. This necessitates a further drop in speed for the required torque. These local electro-

motive forces depend upon the secondary alternations, and therefore vary with the drop in speed, and are greatest at zero speed. This introduces a very complicated condition in the secondary circuits. These magnetic fields, which thread around only the primary or secondary windings, are called the magnetic leakages, or stray fields, or the magnetic dispersion. If the magnetic leakage is relatively large, that is, twenty to twenty-five per cent of the total induction,

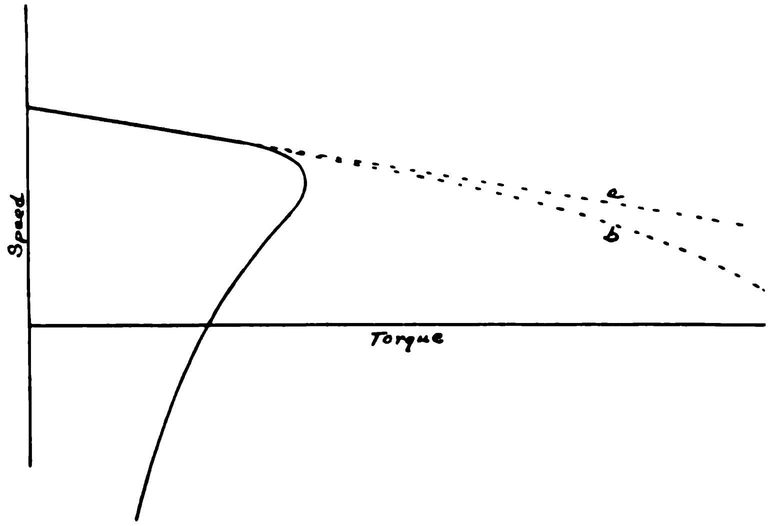



FIG. 5.

and the secondary resistance is low, the speed-torque curve has the peculiar shape shown in Figure 5. This curve shows the torque increasing as the speed falls, until a certain maximum is reached. Beyond this point the torque diminishes with further drop in speed. If the motor is loaded to the maximum torque, a slight increase in load causes a further drop in speed, the torque diminishes and the motor stops. As a consequence, the normal rating of the motor

must be considerably below the pulling-out point. The margin necessary depends upon the nature of the load to be carried.

The starting torque, speed regulation, etc., of the polyphase motor depend upon the form of the speed-torque curves. The different methods of varying the form of these curves will be considered next.

As the secondary electromotive force is that necessary to drive the secondary currents through the windings, it follows that the electromotive force required must depend upon the resistance of these windings. A larger resistance means a larger electromotive force for the required current, and, therefore, a greater number of secondary alternations, or a greater drop in speed. The torque being held constant, any variation of the secondary resistance requires a proportionate variation in the slip. If the slip with a given torque is ten per cent, for instance, it will be twenty per cent with double the secondary resistance, or fifty per cent with five times the resistance. This is true only with the primary conditions of constant applied electromotive force and constant alternations. The secondary resistance may be in the windings themselves; or may be external to the windings, but part of the secondary body; or it may be entirely separate from the machine, and connected to the windings by the proper leads.

Figure 6 shows the speed-torque curves for a motor with different resistance in the secondary circuit. In *a* there is a secondary resistance, which is small. In *b* the secondary resistance is doubled. The maximum torque remains the same, but the slip, for any given torque, is doubled. This starts much better than *a*. In *c*, the resistance is again doubled, and the slip is also doubled. The starting torque is

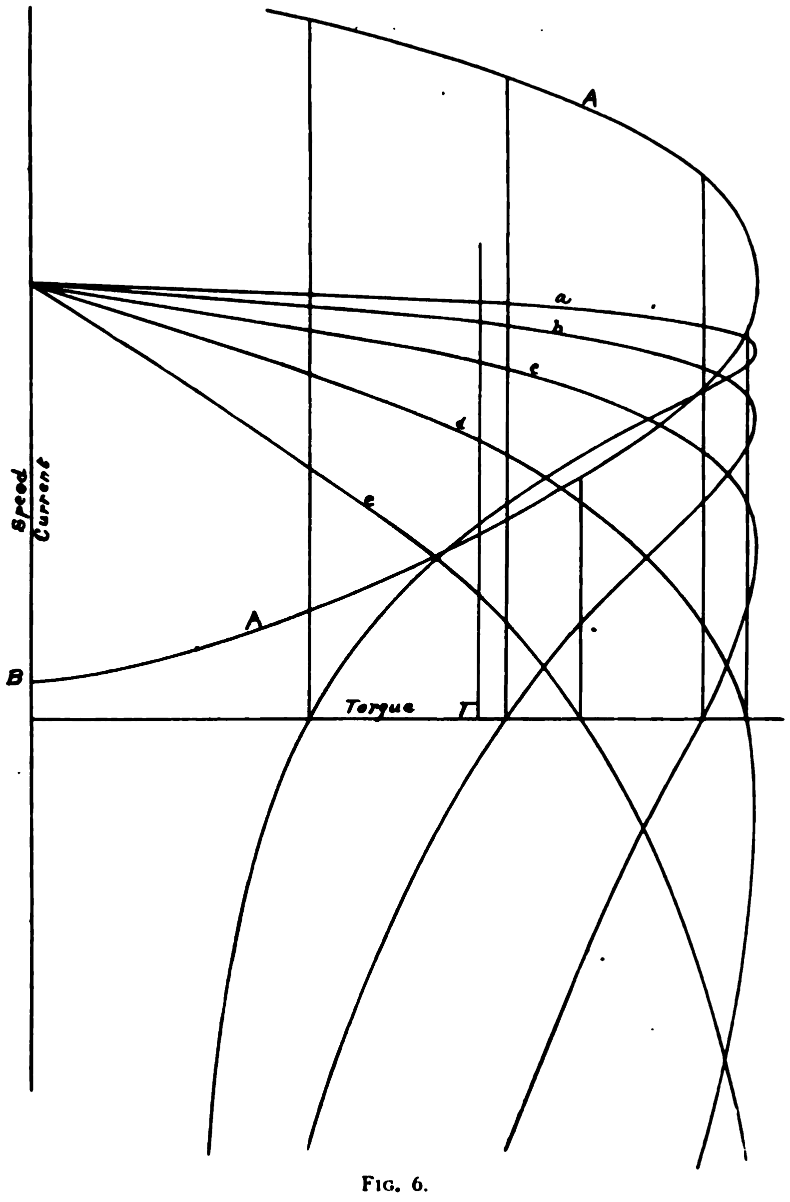



Fig. 6.

increased, but the slip is rather large at the rated torque, *T*. In *d*, the slip is again doubled. In this case the torque is high at start and falls rapidly as the speed increases. In *e*, the maximum torque is not yet reached at zero speed. Continuing these curves below the zero-speed line, that is, running the motor in the reverse direction, we get the general form of these different speed-torque curves. They are all of the same general shape, and all have the same maximum torque.

So far as torque is concerned, *d* is the best for starting. But for running, *a* gives the least drop in speed. Consequently, if a resistance is introduced at start that will give the speed-torque *d*, it should be cut out or short-circuited for the running condition. This is one method of operation that has been much used.

In determining the best starting condition, the current supplied to the primary should be considered in connection with the speed-torque curves. This current may be plotted with the series of speed-torque curves shown in Figure 6. Referring to this figure, *A* represents the primary amperes in terms of torque. Starting at *B* at no-load, or zero, torque, it rises at a nearly uniform rate until maximum torque is approached; that is, below this point the current is nearly proportional to the torque, but beyond this the current continues to increase, and reaches a maximum at the torque represented by zero speed. At reversed speed this current is further increased. This one current curve holds true for all the speed-torque curves, *a*, *b*, *c*, *d*, etc. Comparing the different curves, we see that *a* takes most current at start, and gives low torque; *b* takes less current than *a*, and gives more torque; *c* takes less current than *b*; *d* takes less cur-

rent than *c*, and gives the maximum torque at start; *e* takes less current than *d*, and develops less torque; but the current and torque are very nearly in proportion over the whole range. From this we see that a speed-torque curve of the form of *d* or *e* is decidedly better than *a* or *b* for starting. But for

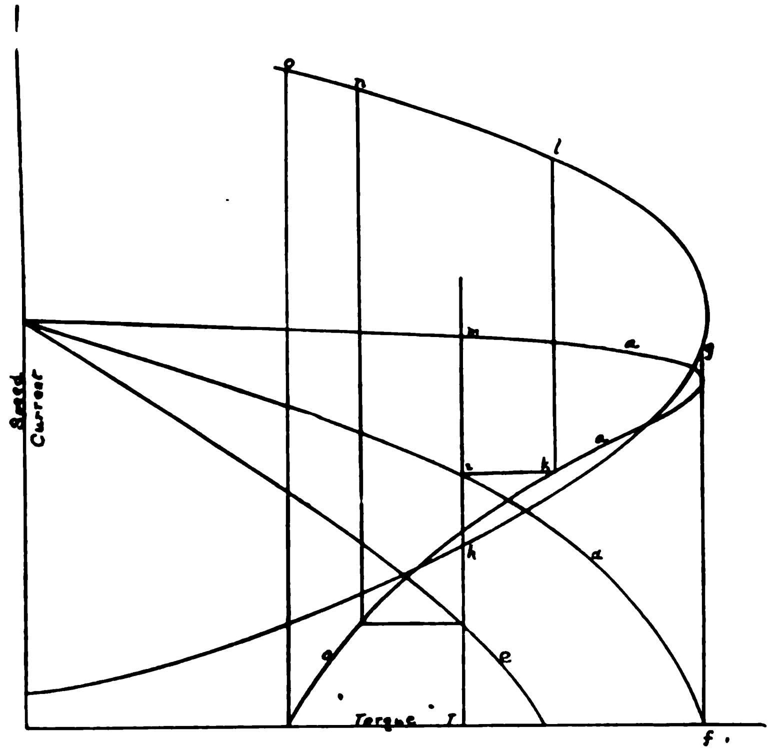



FIG. 7.

running at less than the maximum, there is no advantage, so far as current is concerned, in curve *d* over curve *a*, and the speed regulation of *d* is poor.

Figure 7 represents the conditions of speed, current, etc., when a variable secondary resistance is used at start. The motor starts at *f* on curve *d*, and takes

a current *g*. The current falls to *h*, while the speed rises to *i*, which is at the normal torque at which the motor will run under the given conditions. The speed will remain at this point. Then the resistance in the secondary is short-circuited, and the load is shifted to the speed-torque curve *a*. At the speed *i*, the torque increases to *k* on the torque curve. The current corresponding to this is *l*. As the torque at *k* is greater than at *l*, the motor speed will increase until normal torque is reached again at *m*, while the current falls from *l* to *h*. Consequently, at the moment of cutting out the secondary resistance, there has been a very considerable increase in the current. By arranging the starting resistance in the secondary for more current at start, somewhat less would be required upon switching from *b* to *a*. But if the torque required when speeding up is greater than that at the point where curves *a* and *e* cross each other, the motor will not pull up if curve *e* is used for starting. For, switching from *e* to *a*, the torque falls, and the motor will stop. The current on switching over increases to *n*, and then rises to *o* as the motor stops. In this case the resistance that gives curve *e* is too great, and a lower starting resistance is required. By making several steps of the secondary resistance, so that it may be cut out gradually, the motor may be made to pass through a series of speed-torque curves with much smaller variations of current than shown in the preceding diagrams. This method has been used to some extent, but requires collector rings or a complicated switching arrangement in connection with the motor secondary.

Figure 8 shows the conditions for starting and speeding up, with five speed-torque curves. The motor starts on curve *e* at *f*. The speed rises to *g*. The

motor is then switched to curve *d*, the torque rising to *h*. The speed then rises to *i*. In this way the motor passes successively from *d* to *c*, *b* and *a*, until the full speed is reached. The currents at no time reach very high values.

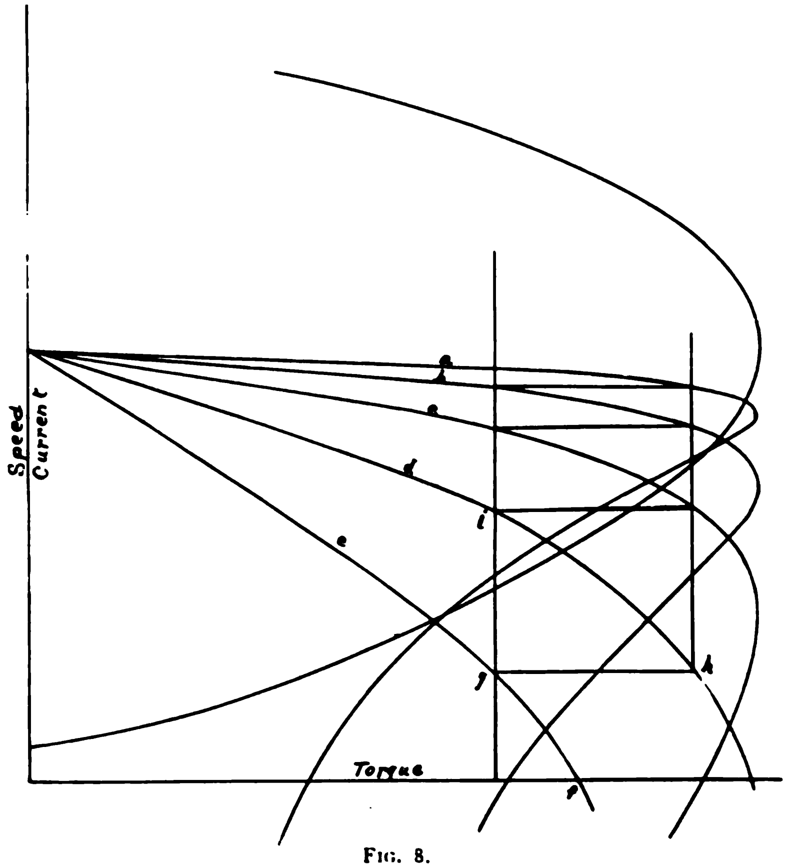



FIG. 8.

Plotting the current in terms of speed, the use of a large number of steps is shown to better advantage. This is shown in Figures 9 and 10. Figure 9 shows the same starting conditions as Figure 7, with curves

*d* and *a*. The current starts at *A*, and falls to *B*. The resistance is then short-circuited, and the current

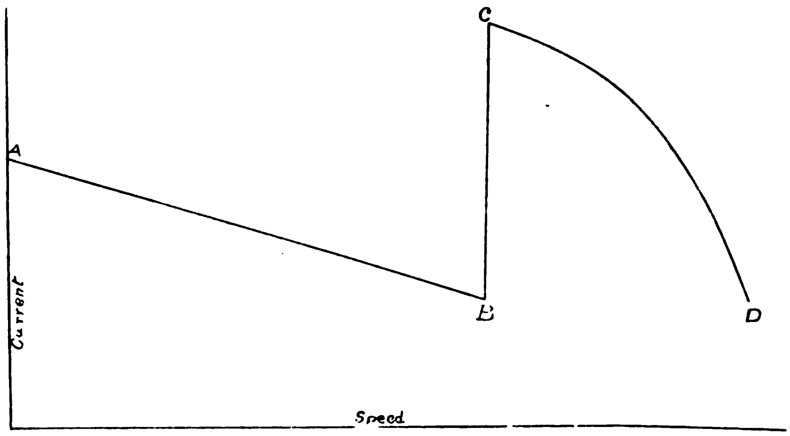



Fig. 9.

rises to *C* and then falls to *D*, which is the same as *B*. If *A* had been higher at start, *C* would have

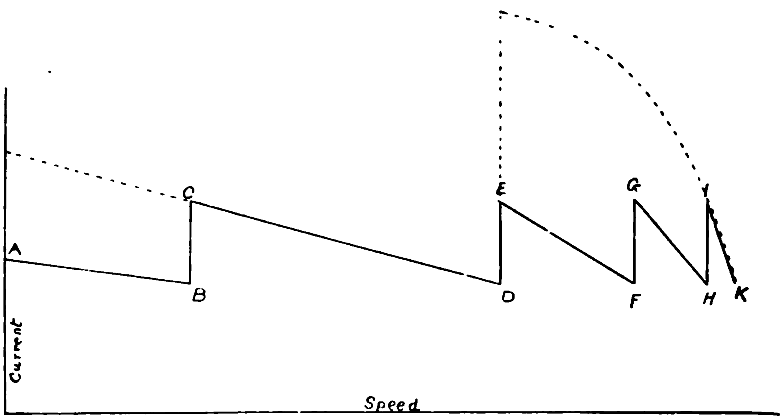



Fig. 10.

been lowered slightly. But, as the time required for passing from *A* to *B* is generally greater than that

from *C* to *D*, *C* may be higher than *A*. If the motor is not required to develop such a large torque when pulling up, then *C* will be lowered, while *A* is unchanged.

In Figure 10, the currents in terms of speed are shown for five steps with the five speed-torque curves of Figure 8. The starting current *A* is low, and none of the currents, when switching from one curve to another, are large. The dotted lines show the corresponding currents for two steps, as in Figure 9.

For variable speed work, such as cranes, elevators, etc., the series of curves in Figure 6 show one method of regulating the speed. By varying the secondary resistance over a wide range, any speed from zero to maximum may be obtained with any torque up to the maximum. This requires the use of collector rings and adjustable rheostats. The variations in speed are obtained by wasting energy in resistance. For a given torque, the same power is expended on the motor whether the speed is zero or the maximum. To obtain a certain torque at start requires as much power as when running at full speed.

An analysis of the motor shows another way in which the speed-torque curves may be varied. In Figure 6, all the curves show a certain maximum torque, which is the same in all cases; but this is with the condition of constant primary electromotive force. By varying the electromotive force applied to the primary, we may obtain a quite different series of curves. Taking, for example, a speed-torque curve of the form *a* in Figure 11, and applying a higher electromotive force to the primary, a curve is obtained of the same shape as *a*, but with a much higher point of maximum torque. Lowering the applied electromotive force, the maximum torque is lowered. The

torques at any given speed are raised or lowered in the same proportion as the maxima are varied. At any given speed, the torques are proportional to the square of the electromotive forces applied. This relation holds good for any form of the torque curve, whether of the shape *a*, *d* or *e*, shown in Figure 6.

The current curves are also shown in Figure 11. They all have the same general shape, but have different maximum values, these being proportional to the electromotive forces applied. The speed-torque curve *a* in Figure 11 has the same shape as *d* in

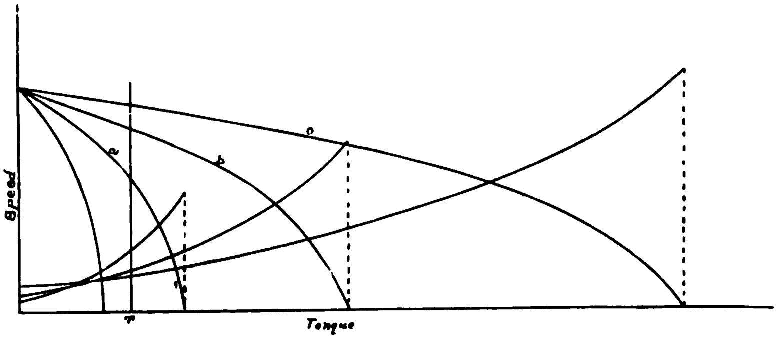



FIG. 11.

Figure 6, which gave too great a drop in speed. In Figure 11, curve *b*, which is the same form as *a*, gives less speed drop for the same torque. Curve *c* gives less than *b*, and has fairly good speed regulation from no load up to normal torque *T*. But this result is obtained at the expense of increased induction in the iron, and large no-load or magnetizing current, due to the higher electromotive force required. If it is possible to obtain a speed-torque curve like *c* in Figure 11, with the normal electromotive force applied, we can obtain good speed regulation from no load up to

the rated torque, and shall be able to start the motor with the maximum torque it can develop. Then by lowering the applied electromotive force, the same form of speed-torque curve will be retained, but the starting torque and starting current may be lowered to any extent desired.

Returning to Figure 5, it was stated that the peculiar shape of this curve, with the torque falling rapidly after reaching a maximum value, was due mainly to magnetic leakage between the primary and

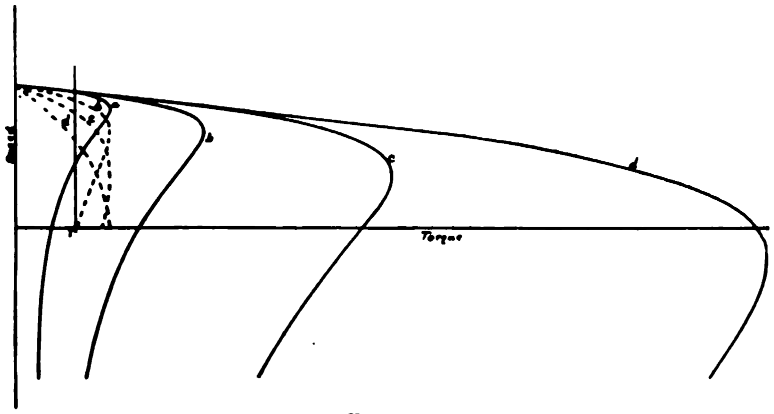


Fig. 12.

secondary windings. But if the motor is so proportioned that the leakage is very small compared with the useful field, the speed-torque curve takes a quite different shape. The maximum torque is increased directly as the magnetic leakage is diminished. This is shown in Figure 12. Here *a* is similar in shape to curve *a* in Figure 6; *b* represents the speed-torque curve with the magnetic leakage reduced one-half; *c* represents it with about one-half the leakage of *b*, and *d* with one-half that of *c*.

In comparing Figures 6 and 12, it may be noted that *a* in one is the same form as *a* in the other, although drawn to a different scale. In Figure 12, *b* has the same shape as in Figure 6, but has a different maximum value. The same is true of curves *c* and *d* in the two figures. By lowering the applied electromotive forces for curves *d*, *c* and *b* of Figure 12, so that the maximum torques are equal to that of *a*, as shown by the dotted curves, we get practically the same curves as in Figure 6.

In Figure 12, *d* gives as good running conditions as curve *a* in Figure 6, having about the same drop

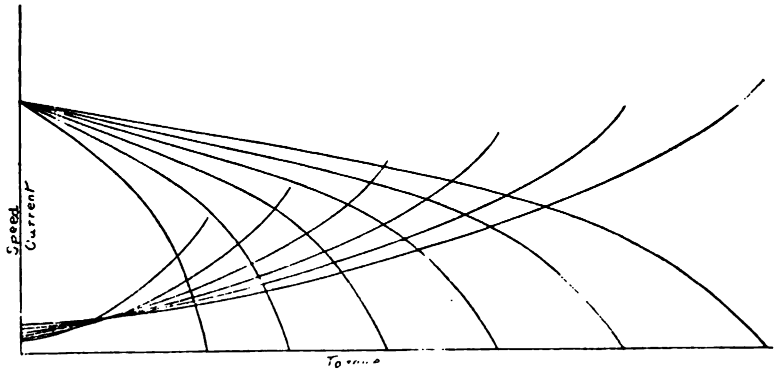



FIG. 13.

in speed at the normal torque *T*. We have, then, in *d* a curve which starts at the point of maximum torque, and which also has a small drop in speed at the normal load. The objection to this curve is that the starting current and starting torque, although in the proper proportion to each other, are both much greater than is necessary or desirable. But by reducing the applied electromotive force at start, lower torques and currents are obtainable. In this way, we may combine good starting and good running con-

ditions in one motor without the use of starting resistances, and with a secondary that has no resistance except that of its own windings. Figure 13 shows the speed-torque and current curves of such a motor, with the applied electromotive force varied over a considerable range.

If but one electromotive force is desired for starting and speeding up, and the motor is then to be transferred to the working electromotive force, the speed-torque curve should preferably have the shape shown in Figure 14. This starts with the desired

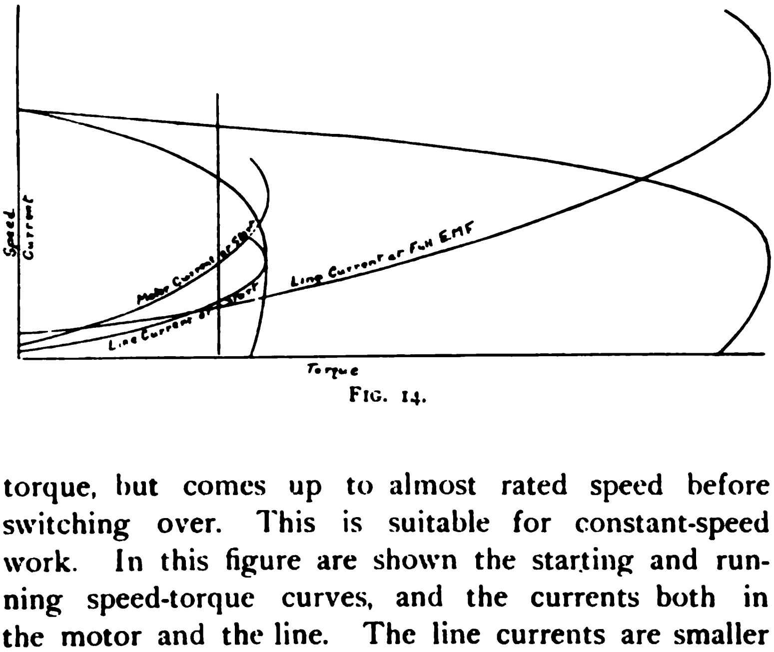



FIG. 14.

torque, but comes up to almost rated speed before switching over. This is suitable for constant-speed work. In this figure are shown the starting and running speed-torque curves, and the currents both in the motor and the line. The line currents are smaller than the motor currents in the ratio of reduction of electromotive force in the regulating transformers.

For cranes, elevators, and variable speed work in general, curves of the form shown in Figure 15 are preferable. The line currents are also shown in this

figure. This series of speed-torque curves shows that a wide range of speed may be obtained by proper variations of the applied electromotive force. The line currents *A*, *B*, etc., practically overlap each other. This means that the line current required with this method of control, is very nearly constant for any given torque, independent of the speed. The same is true of the method of control by varying the secondary resistance. It may be noted that the current for starting, as on curve *C*, for instance, is slightly greater than required for running at the same torque

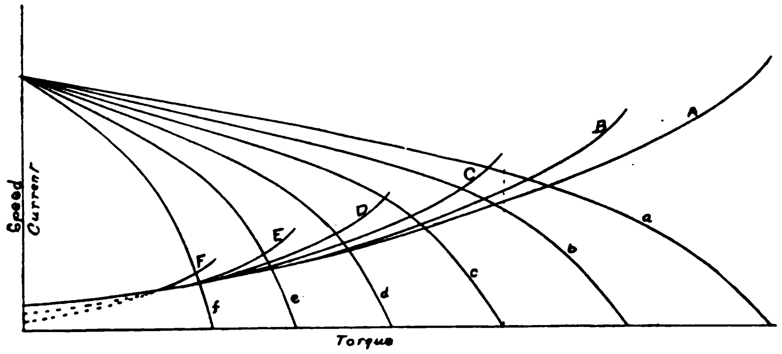



FIG 15.

on *b* or *a*. This is due to the speed-torque curve being somewhat curved at its outer end. With a somewhat higher resistance of the secondary, the curves are more nearly straight, but the drop in speed is somewhat increased on the speed-torque curve for any given electromotive force. In practice, a slight compromise is made between the best possible starting condition and a condition of less speed drop.

A comparison of the methods of control, by varying the secondary resistance and by varying the

applied electromotive force, shows that they give practically the same results in regard to starting, speed regulation, etc. But a motor that has been designed for regulation by varying its secondary resistance, will generally give very poor results when an attempt is made to operate it by the variable electromotive force method. A motor must be especially proportioned for small magnetic leakage when this method of control is to be used. The proportions and the arrangement of the parts are such as may class this as a practically distinct type of motor.

### THE EFFICIENCY AND POWER-FACTOR CURVES

We now come to the other characteristics of the polyphase motor, the most important of these being the efficiency and the power-factor curves. The importance of efficiency is generally appreciated, but the question of power factors appears to be overlooked in most cases, or else is not thoroughly understood.

The efficiency of a polyphase motor is the ratio of the power developed to the true power expended, as in any other kind of a machine. The power developed may be obtained from the speed-torque curves. If the torques are given for one foot radius, and the speeds in revolutions per minute, then the product of any given torque by the corresponding speed, divided by 5,250, will give the power developed in horse power; or torque by speed, divided by seven, gives the power developed in watts. This power, plus the iron, copper and friction losses, gives the true power expended.

The power factor is the ratio of the true power to the apparent power expended. This apparent power

is proportional to the products of the primary currents by the electromotive forces. If there is magnetizing current, and if the motor has magnetic leakage, the primary currents are not in phase with their electromotive forces, and their products represent an apparent power which is greater than the true energy expended. The current of each circuit can be considered as made up of two currents, one of which is in phase with the applied electromotive force, representing true energy, and the other at right angles to the electromotive force, representing no energy. This right-angled component is the one that has an injurious effect on the regulation of the generator, transmission lines, transformers, etc.

The size of this component, compared with the useful current, may be shown by a table:

| Power Factor | Total Current | Useful Component | 90-Degree Component |
|---|---|---|---|
| 100 | 100 | 100 | 0. |
| 99 | 100 | 99 | 14.2 |
| 98 | 100 | 98 | 19.9 |
| 95 | 100 | 95 | 31.2 |
| 90 | 100 | 90 | 43.6 |
| 80 | 100 | 80 | 60.0 |
| 70 | 100 | 70 | 71.4 |
| 60 | 100 | 60 | 80.0 |
| 50 | 100 | 50 | 86.6 |
| 40 | 100 | 40 | 91.6 |

Thus, at ninety-per-cent power factor, for instance, the current that is lagging ninety degrees behind the electromotive force is equal to 43.6 per cent of the total current flowing. This lagging current reacts on the generator, affecting the regulation. In an alternating current generator, a ninety-degree lagging current in the armature coils directly opposes the field magnetization. When delivering a current at ninety-

per-cent power factor, there is over forty-three per cent of this current opposing the field, and at eighty-per-cent power factor, sixty per cent is opposing the field. If the armature ampere turns are normally twenty per cent as great as the field ampere turns, then a load of eighty-per-cent power factor will give an opposing magnetization in the armature of about sixty per cent of the total armature ampere turns. or about twelve per cent of the total field, and the armature electromotive force will be lowered approximately that per cent more than with a load of one-hundred-per-cent power factor.

The inductive effects of the lagging current in the transmission circuits and transformers are much more serious than those from a current that is in phase with the electromotive force. The generator, transformers, lines and motors also have increased losses, due to the larger current required when the power factor is low. An eighty-per-cent power factor in a system means losses, due to heating of conductors, more than fifty per cent greater than with one hundred per cent. These figures indicate the importance of good power factors in an alternating-current system.

The lagging or ninety-degree component of the current in a motor depends upon the amount of the no-load or magnetizing current, and upon the magnetic leakage. Let this lagging component be expressed in per cent of the total current. Also express the magnetizing current in per cent of the total current, and the total magnetic leakage in per cent of the total primary induction. Then the sum of the per cents of magnetizing current and magnetic leakage represents very closely the per cent of the lagging component of the primary current. If, for example, the magnetizing current is thirty per cent and the

leakage is fourteen per cent, the resulting lagging component is about forty-four per cent. From the preceding table, this indicates about ninety-per-cent power factor. A low leakage and a high magnetizing current may give the same power factor at full load as a high leakage and low magnetizing current; but at half load, the per-cent magnetizing current is practically doubled, while the per-cent magnetic leakage is halved. Here, a low magnetizing current is of great importance in maintaining a high power factor. If a high value of this over a wide range is desired, then both the leakage and magnetizing current must be low.

The method of control by varying the primary electromotive force is dependent upon the fact that the motor has a low magnetic leakage. By using certain proportions and arrangements of the windings on the primary and secondary, the magnetizing current may be made comparatively low. Thus both conditions for good power factor are obtained.

With the method of control by varying the secondary resistance, good power factors may be obtained. But the form of secondary winding required when variable resistances are used, tends to reduce both the power factor and the maximum torque.

An elaborate series of tests was made, to determine the best type of winding for the secondary of a polyphase motor. First, two circuits were arranged to give secondary phases ninety degrees apart. The starting, running and maximum-load conditions were determined. Then a three-phase secondary winding was used. This gave a higher pulling-out torque and better power factor than the two-phase. Four phases were tried, and were better than three; and six were better than four. Then twelve phases were tried,

with a gain in maximum torque over six, but not much gain in efficiency. The power factor was somewhat improved. Then the winding was completely short-circuited on itself, all coils being connected to a common ring. This gave a further increase in maximum torque and power factor over the preceding arrangement, but there was very little gain in efficiency. The same primary was used in all these tests. Each time the number of secondary circuits was increased, the power factor was somewhat improved. This was due to the fact that the secondary currents were able to so distribute themselves that the local electromotive forces in the coils, due to leakage, were diminished; or, the magnetic leakage may be considered to have been diminished. This would necessarily give higher pulling-out torques and higher power factors.

Very complete tests were also made to determine the best form of primary winding, and a certain method of distribution of the coils was found to diminish the primary magnetic leakage very considerably. This somewhat increased the maximum torque and the power factor. Utilizing the arrangements of the primary and the secondary windings just described, and otherwise proportioning for small magnetic leakage, a motor may be obtained that has a comparatively low total induction, and yet has a magnetic leakage of but a few per cent. The low induction allows a small magnetizing current and comparatively low iron losses. The low leakage gives a high pulling-out torque, and thus allows good speed regulation, and also good starting conditions, by varying the applied electromotive force.

Motors that are adapted for operation under the conditions of variable applied electromotive forces, with constant secondary resistance, must have the special forms of speed-torque curves shown in Figures 12 to 15, and they may therefore be considered as forming a distinct type. This has received the name *Type C*. This type of motor is always characterized by low magnetic leakage and consequent high pulling-out torque. The secondary has no adjustable resistance, and all regulation is obtained by varying the adjustable electromotive force. The secondary is made the rotating part, on account of the type of winding used, which consists of copper bars placed in tunnels or slots in the core, and bolted to two end rings. There are no bands, and the question of insulation is of very little importance, for the maximum secondary electromotive force does not exceed three volts in a 500-horse-power motor, and is less with smaller sizes. This type of motor possesses several distinct advantages over other forms of polyphase motors. The method of control, by varying the electromotive forces applied to the motor, leads to two very important advantages, one of which is mechanical and the other electrical. With this method of control there are no regulating appliances on the motor, and, in consequence, it may be of the simplest possible form. The electrical advantage is that the motor may be started and controlled from a distance. Thus it may be placed entirely out of reach of the operator. On traveling cranes, for example, this is of especial advantage, for in this case the primary wires only need be run from the operator's cage to the motor. If there are several motors on the crane, there may be one wire common

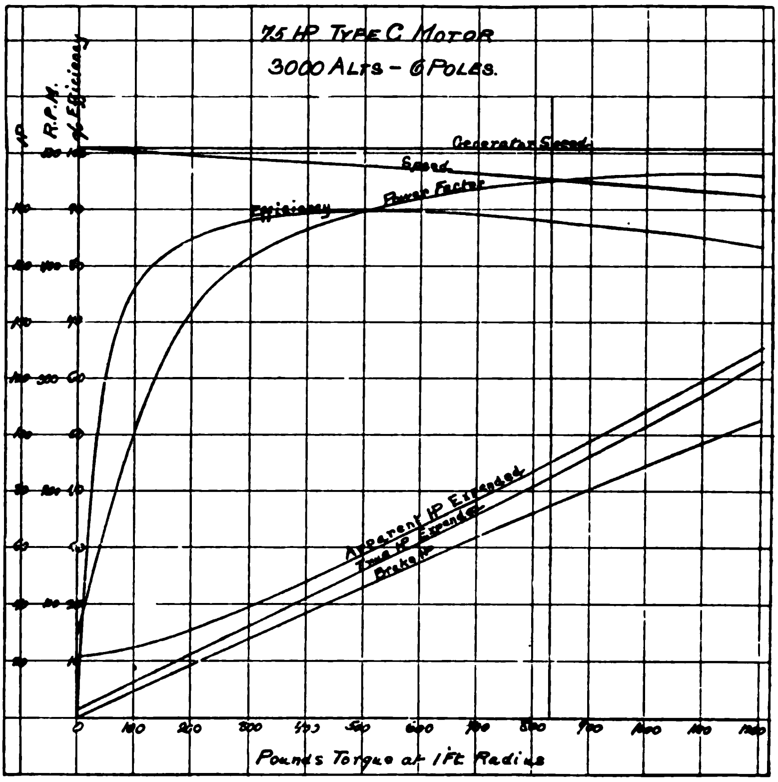
to all the motors, and but two additional wires per motor are required. Thus, for three motors, a minimum of seven trolley wires may be used.

If the variable electromotive forces are obtained from transformers, the switches for operating several motors may be wired to one set of transformers, and the motors may be started and regulated independently. For traveling cranes, one set of transformers is used for the hoisting, bridge and traveling motors, and this set may supply currents at different electromotive forces to all the motors at the same time. A further advantage possessed by this motor lies in the high pulling-out torque. If a heavy overload, or a load having great inertia, is suddenly thrown on a motor that has a speed-torque curve like *a* in Figure 6, the point of maximum torque may be passed for an instant, and the motor will be stopped unless the load is quickly removed. A Type C motor in this case would have its speed pulled down for a moment, but this reduction in speed gives an increased torque, thus enabling the motor to carry the overload.

If the electromotive force of the system is suddenly lowered, the pulling-out torque of the motors is lowered very materially. A reduction of twenty per cent in the electromotive force will lower the pulling-out torque to about two-thirds of its former value. This may be sufficient to stop the motor, even with a temporary drop in the electromotive force, such as would be caused by a momentary short circuit on the lines. But a motor that has a pulling-out point several times as large as its normal running torque, is very rarely in danger of being shut down from this cause. This type of motor has a starting torque from two to four times as large as the full-load running torque, and it is able to start any kind of load. But

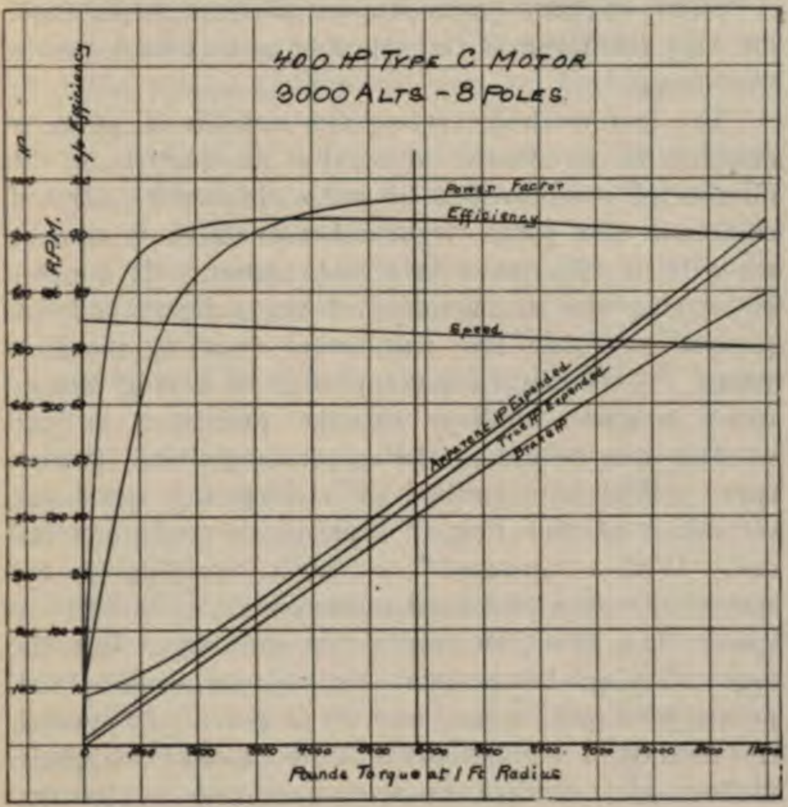
in practice the starting torque is adjusted to the load to be started, by applying a suitable electromotive force, as will be explained below.

A last, but not least, advantage of the Type C is its adaptability for large-size motors. The larger the motor of this type, the lower in proportion can be




its magnetic leakage and its magnetizing current. In consequence, the power factors are very high. The efficiencies are also very good over a wide range of load. The curves for a seventy-five-horse-power, six-pole, 3,000-alternation motor are given; also the

curves for a 400-horse-power, 2,300-volt, eight-pole, 3,000-alternation motor. The power factors of these motors are good examples of what can be obtained on large motors of this type.




VARIABLE SPEEDS WITH POLYPHASE MOTORS

There are six methods of varying the speed of polyphase motors, but some of the mare only applicable in special cases. These methods are:

(1). Varying the number of poles.

(2). Varying the alternations applied.

(3). Motors in tandem, or series-parallel.

(4). Secondary run as single-phase.

(5). Varying the resistance of the secondary.

(6). Varying the electromotive force of the primary, with constant secondary resistance.

Some of these methods are efficient, while some are very inefficient if the speed is to be varied over a wide range.

The first method, varying the number of poles, is efficient to a certain extent, but is limited in the number of combinations of poles obtainable. But if combined with some of the other methods, it may be made fairly effective over a wide range. It consists in varying the arrangement of the primary coils in such a way that the number of resulting poles is varied. This may be accomplished by having two or more separate windings on the primary; or one winding may be used, it being rearranged for different speed. With this method of varying the speed, the secondary of the "cage" type is the only practical one. With a "grouped" or "polar" winding on the secondary, this would need rearranging for the different speeds, just as in the case of the primary. But the cage winding, being short-circuited on itself at all points, is adapted to any number of poles. In general, this method of regulation will allow of only two speeds without great complications, and the ratio of the two speeds is preferably two to one, although three to one may be obtained. The simplest arrangement of winding consists of two separate primary windings; one for one number of poles, and the second for the other. In combination with a variable primary electromotive force, the speed-torque curves being of such shape that this method may be used, the variable-pole method of regulation may be made fairly efficient over

a wide range of speed. But the two windings considerably increase the size of the motor, while the one-winding arrangements are rather complicated. Consequently, we may consider that this method of speed variation will be used only in special cases. The second method, variable alternations, is theoretically the ideal method; but it is practically limited to a few special applications, for we have as yet no commercial alternation transformer.

In a few cases, where but one motor is operated, the generator speed may be varied. If the generator is driven by a water-wheel, its speed may be varied over a wide range, and the motor speed will also vary. If the generator field be held at practically constant strength, then the motor speed may be varied from zero to a maximum at a constant torque with a practically constant current. This is a convenient method of operating a motor at a distance from the generator. The speed of the motor may be completely controlled by an attendant at the generating station.

Figure 16 shows the speed-torque and other curves of this motor when operated at 7,200, 3,600, 1,800 and 720 alternations per minute, or at one hundred, fifty, twenty-five and ten per cent of the normal alternations. The speed-torque curves are *a*, *b*, *c* and *d*, corresponding to the above alternations. The current curves are *A*, *B*, *C* and *D*. This figure shows that for the rated torque *T*, the current is practically constant for all speeds, but the electromotive force varies with the alternations. Consequently, the apparent power supplied, represented by the product of the current by electromotive force, varies with the speed of the motor, and is practically proportionate to the power developed.

The third method is to run motors in tandem parallel. In this arrangement, the secondary of one motor is wound with a grouped or polar winding to give approximately the same electromotive force and number of phases as the primary. This secondary is connected to the primary of a second motor. The secondary of the second motor may be closed on itself, with or without a resistance, or may be connected to the primary of a third motor, etc. The

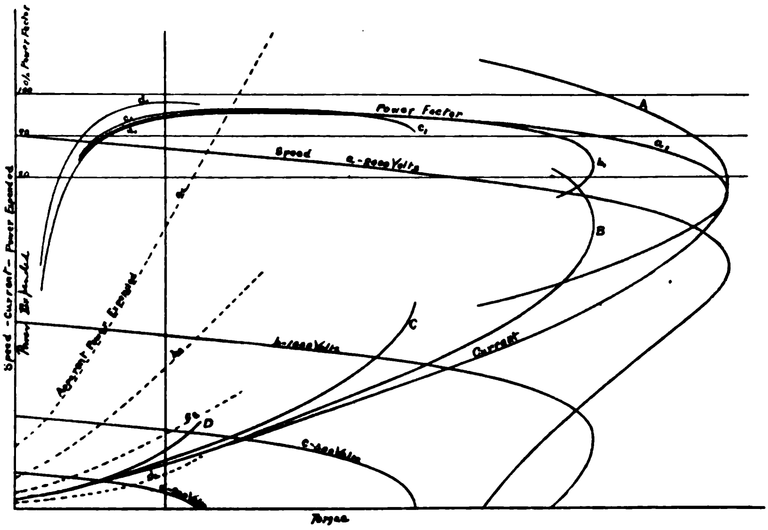


FIG. 16.

arrangement with two motors is shown in Figure 17. At start, motor Number 1 receives the full number of alternations on its primary, and its secondary delivers the same number to the primary of motor Number 2. Both motors will start. As motor Number 1 speeds up, its secondary alternations fall. At about one-half speed, its secondary alternations are about one-half its primary, and motor Number 2 receives one-half the alternations of motor Number 1; it also

tends to run at half speed. Therefore, if both motors are coupled to the same load, this half speed is a position where the two motors tend to operate together. By connecting both primaries across the line, both motors will be run at full speed. Thus, with two motors, two working speeds may be obtained. This method always required at least two motors. Its application is limited to a few special cases.

The fourth method—the secondary run with a single circuit closed—will give a half speed, and with two or more circuits closed, will give full speed. But the power factor at the half speed is very low, and the efficiency is not nearly so good as when run at full speed. This may have a few special applications. Figure 18 shows this arrangement.

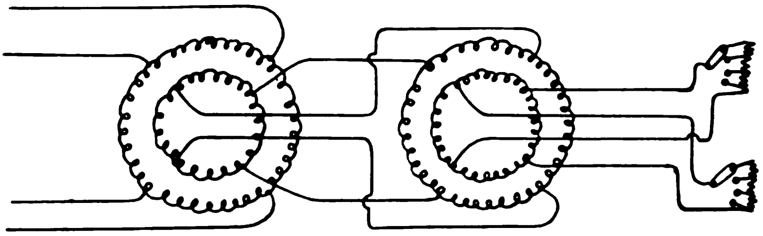


FIG. 17.

The fifth method of regulation is by resistance in the secondary. This has been considered before when the speed-torque characteristics were shown. This will not give constant speed except with constant load, as the speed-torque curve with a relatively large resistance is a falling curve. At heavy torques, the motor will run at very low speeds, while with light loads it will run at almost full speeds. The speed regulation will be similar to that of a direct-current shunt motor, with a resistance in circuit with the armature. To

hold constant speed with variable load, this resistance requires continual adjustment.

The sixth method—that in which the primary electromotive force is varied while the secondary resistance is held constant—gives the same results as the fifth method, as the speed-torque curves are similar. To hold a constant low speed, the electromotive force must be varied continually if the load is changing. Like the fifth method, this is not efficient at low speeds, as the reduction in speed is obtained by means of a corresponding loss of energy in the secondary circuits.

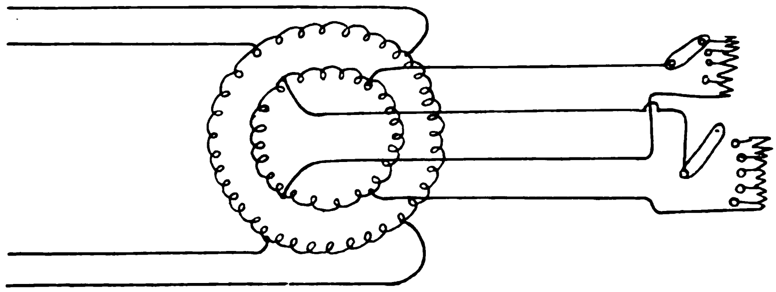


FIG. 18.

For crane work, hoisting, etc., where it is necessary to run at reduced speed for but a portion of the time, either of the methods five or six is satisfactory, but method five requires the use of a variable secondary resistance, and there must be a set of secondary leads carried out to a rheostat if the speed changes are to be gradual. This introduces complication, especially on a crane where several motors are to be controlled. In this case, there must be trolley wires for both the primary and the secondary circuits of each motor. But by method six the control is effected in the primary circuit, and only primary trolley wires are

needed, and these may be controlled from one pair of transformers, as explained before. The sixth method is therefore the simplest and most practical one to use for hoisting, etc., and will be found to present many advantages for all classes of work, whether speed regulation is important or not.

### METHODS OF VARYING PRIMARY ELECTROMOTIVE FORCE FOR TYPE C MOTORS

There are several methods of varying the electromotive force applied for starting and varying the speed on the Type C motors. These may be classified under thiee headings:

(1). Varying the electromotive force from the generator.

(2). Varying the electromotive force by transformers.

(3). Varying the motor connections.

### VARIABLE ELECTROMOTIVE FORCE FROM THE GENERATOR

This may be obtained in several ways. The generator may be run at low speed, with the field charged. This gives lower electromotive force and lower alternations at the same time. This is adapted only to places where all the motors are to be started at once.

The generator may be run at normal speed and its field charge lowered. This gives the normal alternations with lower electromotive force. This is practicable only where all the motors are to be started at once.

A third method is to so arrange the generator windings that two or more electromotive forces for

each phase may be obtained. A lower electromotive force may be used at start, and a higher for running.

The different arrangements of the generator windings for this purpose are as follows:

If the armature has but one winding closed on itself, like a direct-current machine, two or three phases may be taken off. For two phases four leads are used. Figure 19 illustrates this. Between 1–3 and 2–4 is the maximum electromotive force, and between 1–2, 2–3, 3–4 and 4–1 there is 0.7 the elec-

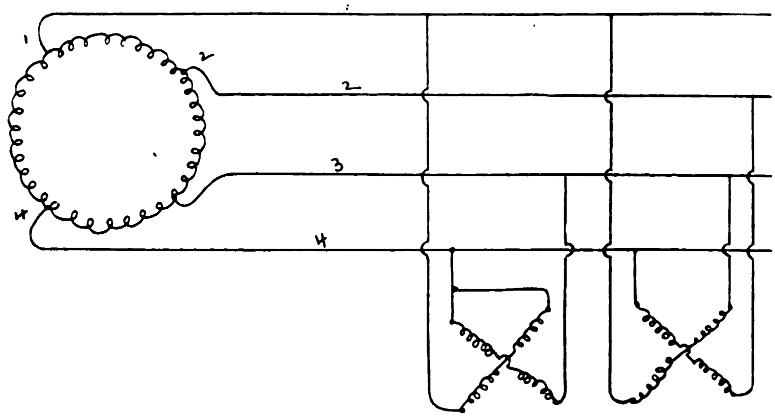



Fig. 19.

tromotive force of 1–3. 1–2 is at quarter phase to 4–1 and 2–3, and 3–4 is at quarter phase to 2–3 and 4–1. Therefore, across any two adjacent side circuits, we have quarter-phase circuits of 0.7 the electromotive force of the main circuit. A motor may be started on any adjacent side circuit and then switched to the main circuit. This method is well-adapted for local plants, where the generator electromotive force is 200 or 400 volts. If there are many motors to be started, and the starts are numerous, it is advisable to wire

the starting switches so that the various motors are started on different side circuits.

If the generator winding is of the "open coil" type, a similar arrangement may be obtained for two phases. The two windings may be connected to the

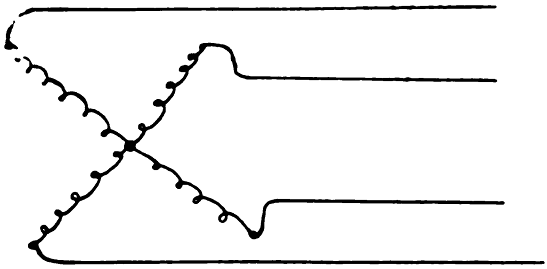


FIG. 20.

middle point, thus giving side circuits of 0.7 electromotive force. This is shown in Figure 20.

Three-phase connections do not allow any very convenient combinations with the generator winding.

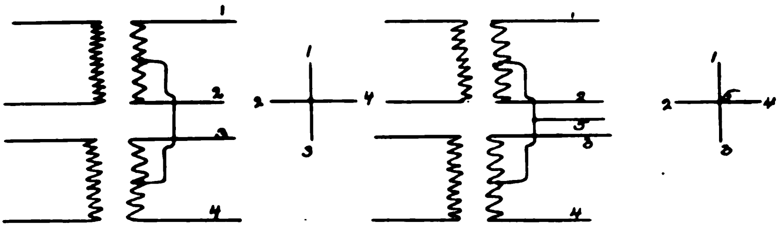


FIG. 21.

A fourth wire may be run which will give about 0.58 electromotive force for starting.

### VARIABLE ELECTROMOTIVE FORCE FROM TRANSFORMERS

This method, varying the electromotive force by means of transformers, admits of many different com-

binations. Several of the simpler forms will be given :

(1). The transformers may be so connected that two or more electromotive forces may be obtained.

For two-phase, the secondaries may be connected together at the centre, as shown in Figure 21. This gives two main circuits, and four side circuits of lower electromotive force. If an extra wire be carried out from the point 5, then 1–5, 2–5 will form a two-phase combination for 0.5 voltage, while 1–2, 2–3 form a two-phase combination for 0.7 voltage, and 1–3 and 2–4 give full voltage.

Another method is to connect the secondaries at

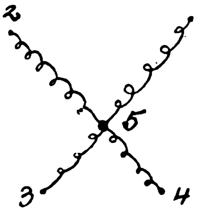



FIG. 22

one side of the center, as shown in Figure 22. Then 3–5 and 4–5 give one electromotive force ; 1–5 and 2–5 give a higher electromotive force, and 1–3 and 2–4 give full electromotive force.

These combinations are useful in certain cases, but are not as general in their application as the following method :

(2). Auto-transformers with loops brought out for lower electromotive forces.

In this method, no special combinations of the lines, lowering transformers or generators are made, but, in connection with each motor, a small pair of auto or one-coil transformers is used for starting. If

speed regulation is also desired, as for cranes, the auto-transformers are made larger. From these auto-transformers several loops or connections are brought out. These are connected to contact plates on dials for controllers, such as are required for regulating the speed. This is shown in Figure 23. But for starting purposes only, when but one loop from each transformer is used, a pair of switches are used in connection with the transformers. With the switches open, the motor is disconnected. Throwing one direction

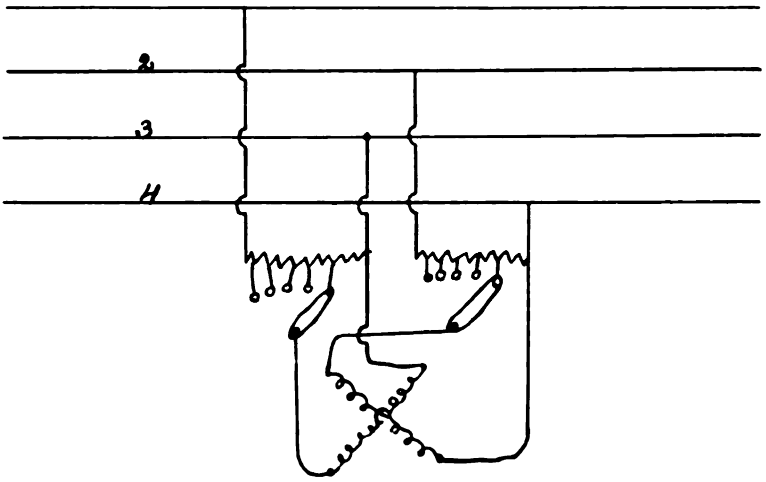



FIG. 23.

starts the motor and brings it up to almost full speed. The switches are then thrown over to full electromotive force.

Two small transformers in a case with one four-jaw, throw-over switch, form what is called an "auto-starter." This is readily arranged for either two or three-phase circuits and motors. This makes the most flexible arrangement for starting, as the motor may be put at any location, and the auto-starter may be put

in the most convenient position. It also loads all the line wires equally at start, and each motor and starter really form a unit separate from all the others. One pair of transformers may be connected to several sets of switches, and thus be used for starting several motors. Where motors are close to reducing transformers, the secondaries of the transformers may have loops brought out, to which one or more switches are connected. The primaries of the transformers may have loops connected to proper switches, and the num-

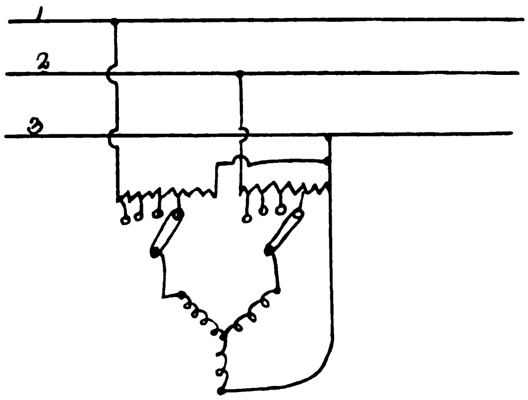



FIG. 24.

ber of primary turns in the circuit may be varied instead of the secondary. This is applicable when the transformers supply only one motor, or when several motors are started at the same time. A regulator with secondary movable with respect to the primary may be used. Regulators of this type vary the electromotive forces without any "make" or "break" devices, and consequently have no sparking tendency. But they are in general too complicated and costly to be able to compete with the transformer with loops.

VARYING THE MOTOR CONNECTIONS

This is not a method for changing the electromotive force applied; but with a given electromotive force the number of turns in series are varied, and the effect is the same as varying the applied electromotive force. This method is rather limited in its application without undue complication. The simplest case for the two-phase is a series-parallel combination of the windings of each phase. This is equivalent to using 0.5 electromotive force at start. For three-phase, series-parallel may be used, or the winding may be thrown from the star system of connection at start to the delta system for running. This is equivalent to using about 0.6 electromotive force for start. But, as the star connection is preferred for the running condition, this combination is not advisable.

CHOKE COILS OR RESISTANCE IN THE PRIMARY

There is a fourth method of regulation which may be mentioned, but which is not advisable in general practice. This is the use of choke coils or of resistance in the primary circuits of the motor, to reduce the electromotive force. These really give varying electromotive forces. With choke coils, the power factor at start is lowered, with correspondingly bad effect on the generator and system. With ohmic resistance in the primary circuit, the reduction of electromotive force is accompanied by a consumption of energy in the primary circuit which in no way represents torque.

The President: Gentlemen, I am sure we are all very much obliged to Mr. Lamme for the paper that he has prepared and read this morning. I am very sorry that we shall not be able at this morning's

session to give it the time that it deserves for discussion. I also regret that, in view of the lateness of the hour, I shall have to reserve the paper by Lieutenant Patten, on "Frequency Transformation," until the first order of business this afternoon. As you are all aware, we have not yet had an executive session. A good many of our active members have been asking to have an executive session this morning, as they are obliged to leave town. I am, therefore, going to adjourn the regular session of the convention until half-past two this afternoon.

After the remaining papers are read we can have a discussion on this paper and on others that have not yet been taken up.

I wish to convene an executive session forthwith.

The convention adjourned to executive session.

## SIXTH SESSION

The meeting was called to order at 2.30 p. m. by President Nicholls, who announced the first order of business to be a paper by Lieutenant F. Jarvis Patten.

LIEUTENANT PATTEN: Mr. President and Gentlemen: I have made this paper less lengthy than I should had I attempted a general discussion of the subject. I found that would make the paper too long for the time that would probably be afforded by the business of your convention, so I restricted it to a discussion of a new solution of this problem which has but recently occurred to me, and I think this is the first time it has ever been put in print.

# FREQUENCY TRANSFORMATION

Transforming the frequency of alternating currents seems to be the only alteration of these exceedingly mutable forms of electric energy that has not yet become an industrial requirement; it is by no means certain, however, that it will not become one at an early day.

Three possible transformations of alternating current are evident in the nature of things; they are:

That of voltage—from a higher to a lower electromotive force;

That of phase—from a given number to a greater or less number of independent currents, and

That of frequency—from a given periodicity to a higher or lower rate of alternation.

The first and most obvious of these was the *raison d'etre*, and whole foundation, in fact, of alternating current practice.

The second was but a tardy outgrowth of multiphase current working, and its efficacy and value were neither seen nor understood by its earlier inventors, no use being made of this order of transformation for several years after its first reduction to practice, in 1892.

The third is now apparently going through the same embryonic stage of tentative solution, while electrical engineers are still at a loss to say to what extent frequency transformation will be used when a good solution of the problem is given. This, however, was precisely the case with phase transformation four

or five years ago, the importance of which is comparatively recent knowledge.

One thing, however, is certain ; at times, we should like a comparatively high frequency for one use, and another relatively low one for another use on the same circuit; but at present we cannot have both from the same generator, thus compelling a sort of compromise in the selection of the frequency that a system of distribution shall be given, and this necessarily to the disadvantage of some part thereof.

For power distribution, we should prefer a comparatively low frequency for motors, rather below sixth than above, but so low a rate is not the best for lighting; hence the compromise if both are to be operated from the same circuit.

Probably the chief reason why frequency transformation has not been more seriously considered, is because no really good or simple solution of the problem has yet been presented; all thus far published being burdened with a complexity of commutating devices, rings and revolving brushes, that render such systems altogether objectionable.

I think I was the first to show a system of frequency transformation, in a paper before the American Institute of Electrical Engineers, in 1891. The essential features of that system are shown in Figure 1. Briefly, a gramme armature has a primary winding, so connected to its commutator that it will turn through a certain arc, say, one-sixth of a revolution for each cycle of the alternating current ; while a secondary winding of the same ring has two diametrically opposite points, connected each to a ring collector.

The system by which the primary winding is connected to its commutator makes such a motor self-

starting with a single-phase supply, and a second commutator, reversely connected to the first at alternate segments, gives a direct current for the field excitation. This apparatus will transform a single-phase alternating current of a given frequency to either single or multiphase alternating currents of one-sixth the given frequency. I need hardly say, however, that, simple as this may seem on paper, the two com-

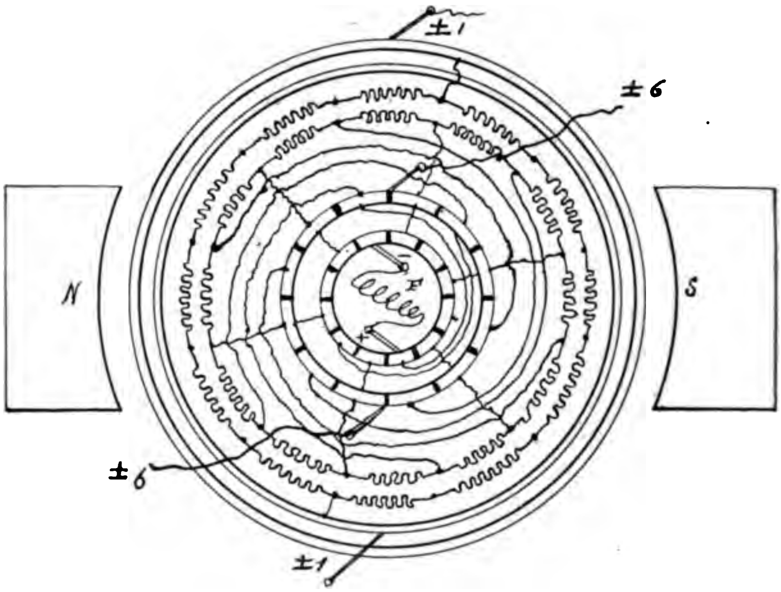



FIG. 1.

mutators render the device unacceptable to American practice, and no machine with even a single commutator or revolving brush can be regarded as a solution of this apparently difficult problem.

Since 1891, only five United States patents have been issued for frequency transformers. It will serve no purpose to refer to them here in detail. They all

come under two heads: One has a multiplicity of revolving brushes, and commutators with rings enough

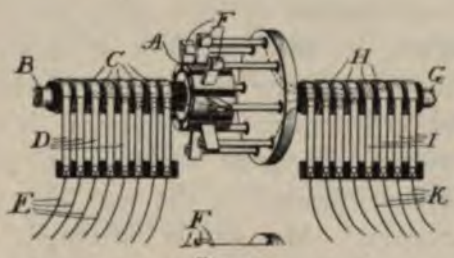



FIG. 2.

to make one dizzy, as evidenced by Figures 2 and 3, taken from one of the patents; and the others are

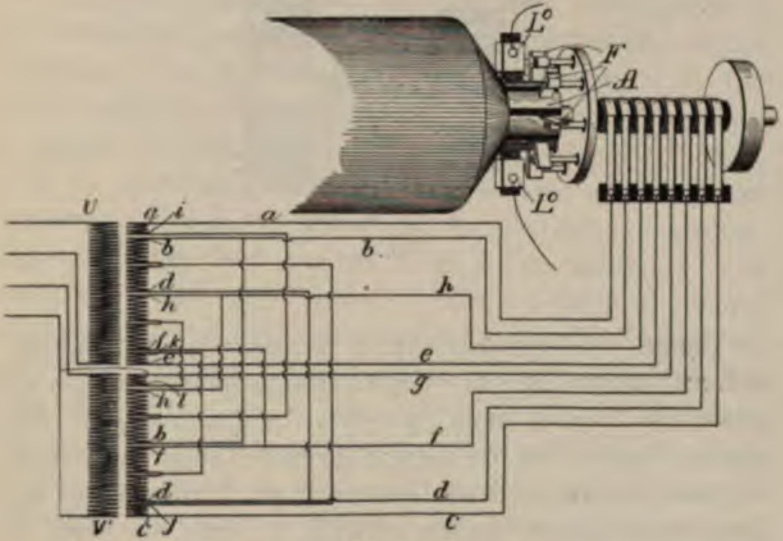



FIG. 3.

simply motor-dynamo systems, and are not, strictly speaking, frequency transformers at all, such as that shown in Figure 4, taken from another patent.

Both systems are self-evident in principle and operation. As concerns the first, it goes without saying that, inasmuch as every direct current is built up of a greater or less number of alternating currents in multiphase relation, so, by a process of analysis, it is a simple matter to separate them into distinct circuits; and then, by a process of synthesis, it is equally simple to recombine them as we like, to produce any new combination desired in the way of phase or frequency alteration. My earlier attempt, outlined in Figure 1, was a little in advance of this.

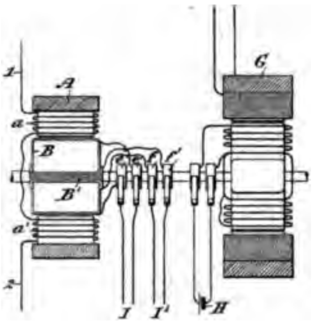



FIG. 4.

Again, it is evident that if we have an alternating-current motor of any description capable of giving power, it can be made to drive a generator of any sort of current or frequency desired; such makeshifts are not transformers of frequency, as I understand the term, and before going further it may be well to define a frequency transformer, as I conceive it.

Such a device should be a self-contained apparatus, in which all the parts are electrically or magnetically interdependent, the function of which is to induce in a secondary circuit an electromotive force of different

periodicity from that of the primary or inducing circuit and source of supply. Inasmuch as frequency is always the result of a relative motion of one part of a generating apparatus with respect to another, thus setting up a corresponding rate of change of induction, so it may be presumed true that changing the frequency of alternating currents implies changing the relative motion of inducing and induced parts with respect to each other, from which it may be further inferred that a moving part is indispensable.

In the apparatus I shall now describe, I obtain this change in the rate of induction by a novel form of electromagnetic motor, which is an independent part of the transformer system, and which, in conjunction with the currents of altered frequency, determines the degree of transformation. A brief description of this motor is necessary to a clear understanding of the apparatus. It is shown in vertical elevation in the lower half of Figure 5, and in horizontal projection in Figure 6. Its field consists of a toothed iron ring, with a gramme winding, supplied with multiphase currents through the leads $L_1$, $L_2$, setting up a rotating magnetic field in the ring. The armature is a solid iron disc, D, Figures 5 and 6, about the same thickness as the ring, but having a diameter considerably less. It has a raised rib or flange, B, which fits into and travels in a corresponding groove cut into the faces of the inwardly projecting teeth of the ring, Figure 10, or in a track set in the ring, Figure 6. This disc armature is pivoted, as shown, eccentrically to the field ring, with which it remains always in contact at one side of the inner periphery of the latter, and is supported by a spindle, $P_1$, which maintains the disc in stable equilibrium in any position it may assume within the ring. When the ring is energized,

the magnetism attracts the iron disc, and, while holding it in firm contact against the ring at the side, it

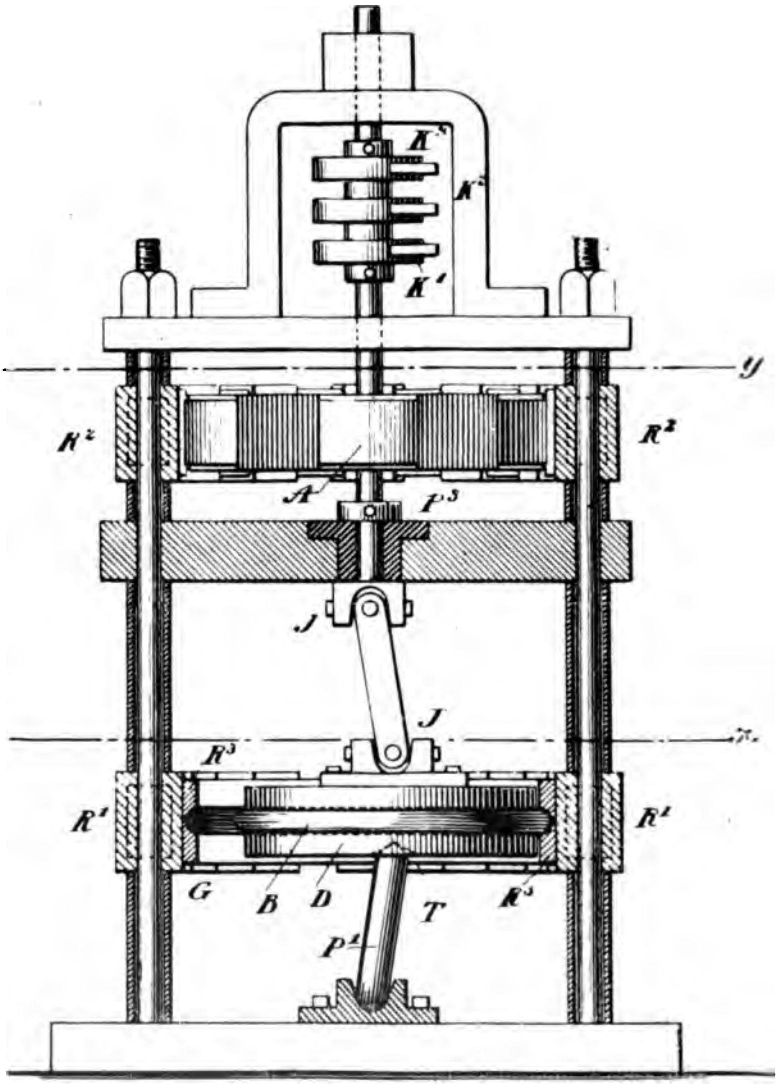


FIG. 5.

causes it at the same time to roll around the inside wall of the ring, following as it must the revolving

polar line of the field. If, however, the rotating magnetism turns contra-clockwise, the disc, in rolling the same way, will revolve in a clockwise direction about its own axis, as indicated by the arrows in Figure 6. Such is the motor part.

A universal joint, J, Figure 5, serves the purpose of rectifying the eccentric movement of the disc, so

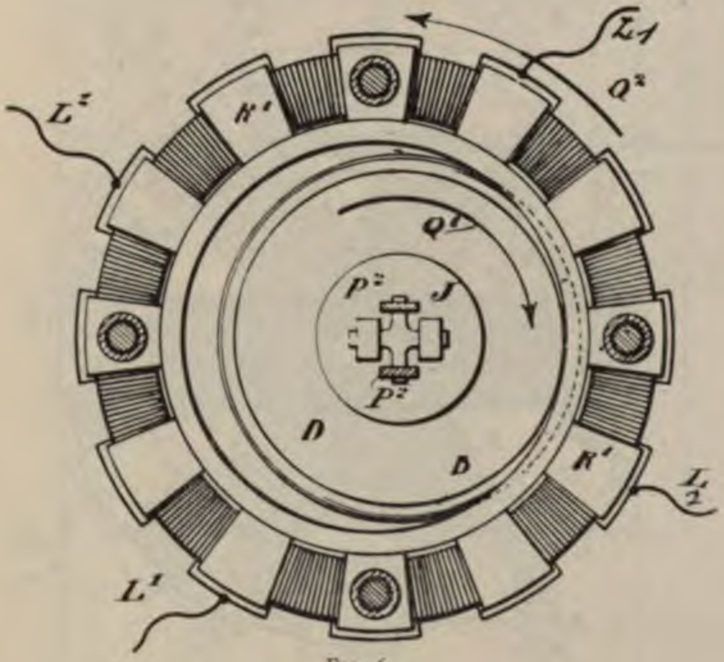



FIG. 6.

that any apparatus carried by the upper spindle, $P_3$, will revolve concentrically with the upper ring, $R_2$, and this ring, with its winding, constitutes the primary or inducing element of the transformer; the three-coil armature, Figures 5 and 7, with its three free ends connected to its three collector rings, Figure 5, being the secondary element or induced circuit.

Such is the apparatus in its entirety, and it may be properly styled a motor transformer for voltage, phase and frequency, as all three functions can be performed as well simultaneously as one or two of them.

The essential peculiarity which adapts it to this use is the following: As the armature disc D has a smaller diameter than the ring inside which it rolls,

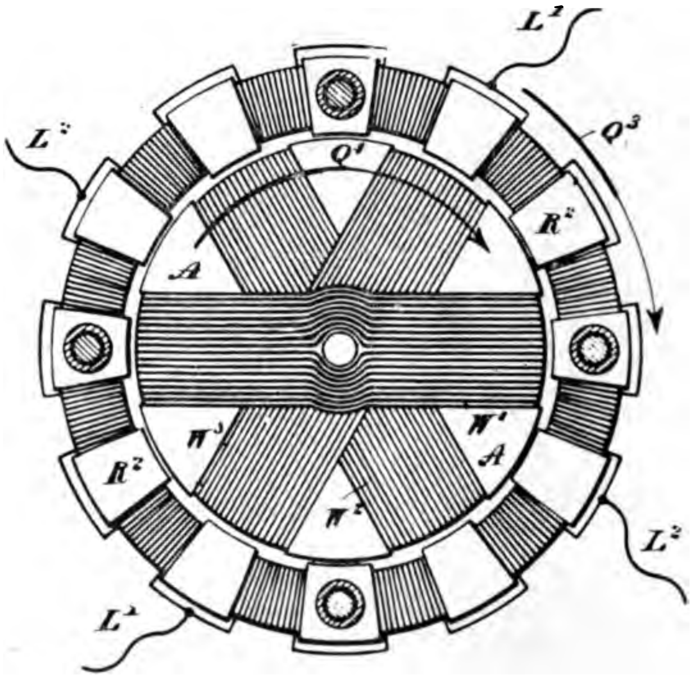



FIG. 7.

so in rolling around the ring from a given starting point to the same point again, the disc will have an entirely independent rate of rotation about its own axis, very different from that of the rotating magnetic field in which it turns, and which will be a function of the difference between the diameters of the disc and ring.

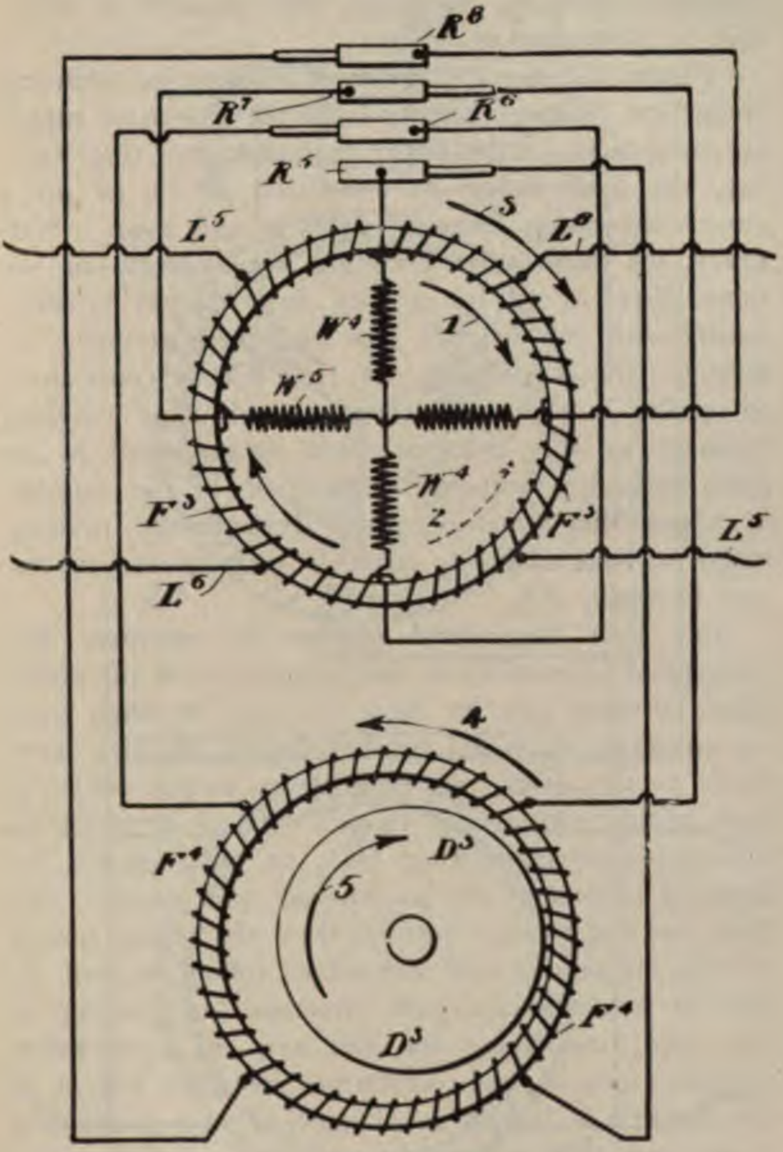



FIG. 8.

Here, then, we have the essential requirement of a frequency-changing apparatus, the operation of which will be somewhat as follows:

Figure 8 being a diagram of circuits for reducing frequency, biphase currents from the source of supply are introduced to the upper or transformer ring winding, the leads being so connected as to set up a clockwise-rotating magnetic field in this ring. Naturally, the transformer armature would rotate in the same direction (if its circuits were closed) synchronously with the field, if free and unconstrained. If, however, the armature is not free, but is constrained to revolve at a slower rate, then multiphase currents (biphase in this instance) will be generated in its coils, having a frequency determined by the number of times the armature turns through the rotating magnetic field while the latter is making one revolution in space.

Let such constrained motion be assumed, and consequent generation in the armature coils of multiphase currents, and let these currents be taken from the collecting rings and brushes thereon through leads down to the lower ring winding or motor field, the leads being so connected to this winding as to set up a contra-clockwise-rotating field, or one opposite in direction to that of the transformer field above. This done, and the biphase currents from the source turned on, the motor disc will commence rolling around its ring in a contra-clockwise direction, but turning at the same time about its own axis in a clockwise direction, carrying the transformer armature with it in the direction of its own revolving field, as it would turn if free and unconstrained by the motor disc, but at a rate of speed of rotation identical with that of the disc about its own axis, which is much slower than

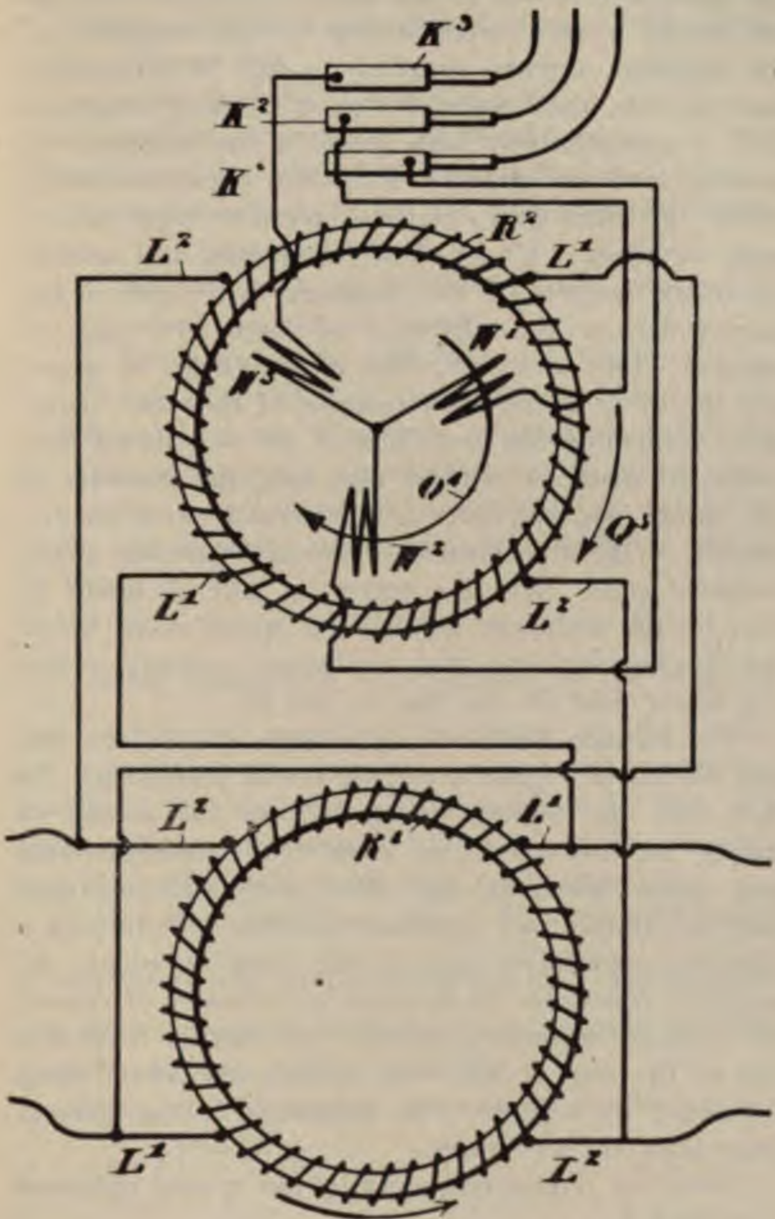



FIG. 9.

the speed of rotation of the transformer field, the latter having a rate corresponding to the frequency of the biphase currents supplied to it. We therefore have in this transformer system a rotating magnetic field of comparatively high speed in the primary ring winding, and an inclosed secondary circuit revolving within the latter at a comparatively low speed in the same direction. Under these conditions the induced secondary currents of the armature will have a frequency due to the difference of these two rates of rotation. One of them, that of the field, is given, and the other is the axial rotation of the disc—necessarily something less than that of its own motor field (when its diameter is more than half the diameter of the latter), and the latter being identical with the frequency of the transformed or induced currents in the armature coils. The disc acts as a sort of brake or load on the armature, holding its speed down below the synchronous rate, thus producing a slowly revolving motor field for the disc to roll in.

To increase frequency, a system of circuits like that shown in Figure 9 will be found preferable. In this case, the biphase currents from the source of supply are introduced to both the transformer-field and motor windings, and the connections are such that the transformer armature and disc will turn in a direction opposite to that of the field in which the armature revolves. In this case, as a matter of course, the induced secondary currents will have a frequency due to the sum of the two motions instead of their difference as before. The following is the general analysis of the two cases:

*First*, to reduce frequency by the system indicated in Figure 8.

Let $n$=the frequency of the primary currents.

$n$=the revolutions per unit of time of the transformer field.

$p$=inside periphery of motor ring.

$q$=outside periphery of the motor disc.

From these it is required to determine

$y$=revolutions made by the transformer armature in a unit of time.

$y$=rate or speed of rotation of the motor disc about its own axis, and

$x$=frequency of the transformed currents.

$x$=rate of rotation of the motor field.

Evidently, if the frequency is reduced, $y$ will be less than $n$, and the transformer armature will turn $n-y$ times a second, which must therefore determine $x$, the rate at which the motor field rotates. Hence we have:

$$n-y=x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

$\frac{p-q}{q}$ is the measure of the difference of the ring and disc peripheries expressed in terms of the latter, and represents that fraction or part of a complete revolution that the disc will make about its own axis while rolling once around the ring, or in the time that the motor field makes one revolution.

In the time, therefore, that the motor field makes $x$ revolutions, the disc will make $x\left(\frac{p-q}{y}\right)$ revolutions and this value must be equal to $y$, because the disc and armature are rigidly connected.

Hence, by substitution in equation, we have:

$$n-x\left(\frac{p-q}{q}\right)=x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

$$\text{from which,} \quad x=\frac{nq}{p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

giving the frequency of the transformed currents in terms of n, p and q, known.

Suppose x is given, and it is required to determine the diameter that the disc should be given to obtain this frequency with a given diameter of motor ring. From equation (1) we obtain

$$\frac{p-q}{q}=\frac{n}{x}-1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

For example, in the former case let the primary frequency be $200=n$, ring diameter $24=p$, and disk diameter $8=q$; then from (3) we have

$x=\frac{200 \times 8}{24}=66.6$, or the transformed currents will have a frequency of 66.6, or one-third the frequency of the primary currents.

In the latter case, given a primary frequency of $200=n$, a secondary frequency of 66.6, to determine what relative diameters to give the ring and disk to get this result, we have from (4) $\frac{p-q}{q}=\frac{200}{66.6}-1=2$, whence $p=3q$, or the disc, to effect this transformation, should be one-third of the diameter of the ring.

To increase frequency, the system of circuits shown in Figure 9 is preferable. Here, the primary currents from the source of supply are taken to both field windings, so that in this case the value y becomes equal to $n\left(\frac{p-q}{q}\right)$, and we have from (2), remembering that the two rates of rotation must now be added,

$$n+n\left(\frac{p-q}{q}\right)=x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

is the transformed frequency, and is one due to the sum of the two rates of rotation, field going one way and armature the other.

Thus, as before, let $n=200$, $p=24$, $q=8$,

$$\text{then } x=200+200\left(\frac{24-8}{8}\right)=600,$$

or the frequency in this case will be three times the primary rate.

Figure 10 shows a modified form of the disc motor, designed to insure strong magnetic action.

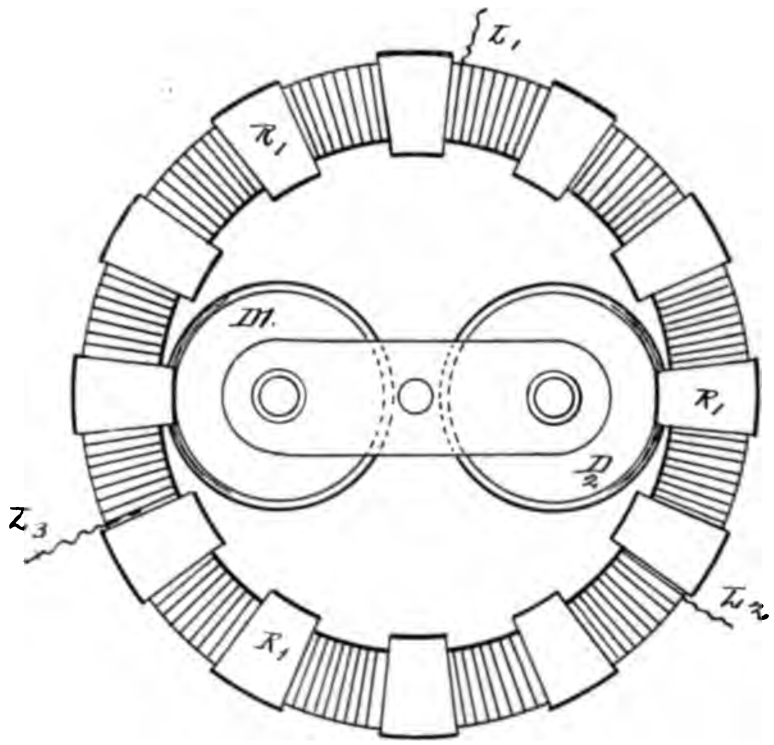



FIG. 10.

When the disc is nearly as large as its containing ring, one disc will answer the purpose; but when it is less than half the diameter of the ring, two diametrically opposite discs, joined by a yoke, should

be used, thus making a perfectly closed magnetic circuit.

We evidently have here a comparatively simple apparatus, from which almost any desired frequency can be derived from a given frequency, while the system is entirely free from revolving brushes or commutators of any description, three collecting rings being, in fact, all that is essential for ordinary transformations of voltage, phase and frequency, of which the system appears to be a general solution.

By having a variety of interchangeable motor discs of different diameters, a great variety of transformations can be made with the same machine.

I am sure that the analysis given for the determination of the transformed values is incomplete, inasmuch as it does not take into consideration the interactions between the two motor systems, the true analysis of which would doubtless prove a very intricate problem; the analysis given is based on the assumption that the disc motor runs normally, as if it were free and unloaded, and so drives the armature above. This will doubtless seldom be the case, and the speed of equilibrium to which the apparatus will finally settle down will be something in the nature of a compromise between the exertions of the two machines regarded as independent motor systems.

THE PRESIDENT: Gentlemen, Lieutenant Patten's paper is before you for discussion. If there is to be no discussion, I will express the thanks of the association to Lieutenant Patten for the paper that he has just presented, and which will be printed in the minutes of the proceedings of this convention in due form.

I now call upon Mr. Charles F. Scott, of Pittsburgh, Pennsylvania, to read his paper, entitled "Rotaries for Transforming Alternating into Direct Current."

Mr. Scott read his paper, as follows:

# ROTARIES FOR TRANSFORMING ALTERNATING INTO DIRECT CURRENT

The characteristic of alternating current that gives it a high commercial value, is the facility with which it may be transformed from one pressure to another. It may be economically transmitted at a high pressure over distances for which the cost of conductors for transmission at low voltages is prohibitive, and then transformed to a low pressure at which it may be utilized. The alternating current and the direct current find a common field in low-voltage distribution for lighting and power, and the direct current alone is applicable to electrolytic work and storage batteries. The direct-current system only is used for ordinary street-railway work, and it possesses certain advantages over the alternating current in central stations and isolated plants.

An electric system may combine both the advantages of the alternating current for transmission and the direct current for utilization, if there is a means of transforming alternating into direct current.

## METHODS OF TRANSFORMATION

The simplest arrangement of ordinary apparatus for transforming from alternating to direct current is found in an alternating-current motor driving a direct-current dynamo. The two machines may be mechanically connected by belt or otherwise, or the two armatures may be mounted upon one shaft and the

two fields placed upon the same bed plate. In such an arrangement, the electrical energy of the alternating current is transformed into mechanical energy, which is in turn transformed back into electrical energy, appearing in the form of direct current. The arrangement may be further simplified by using a single field and a single armature with two windings —one for receiving the alternating current and the other for generating the direct current. A further simplification is made by uniting the two windings into a common winding suitably connected, both to collector rings for receiving the alternating current, and also to a commutator for delivering the direct current. This arrangement constitutes the ordinary rotary transformer, rotary converter, or rotary, such as has been finding a widening and important practical application during the last few years.

An armature for a rotary may readily be made from the armature of a direct-current machine by connecting collector rings to certain commutator segments, or to the points in the winding to which they are connected. The part of the armature winding between two collector rings is continuously changing position with reference to the field poles, and is therefore generating a continuously changing electromotive force, which appears as an alternating electromotive force. Such a machine may be operated as a generator, being driven by mechanical power, and delivering either direct current from the commutator or alternating current from the collector rings; or as a motor, receiving either direct current or alternating current and delivering mechanical power; or as a motor-generator (or rotary), receiving direct current and delivering alternating current, or receiving alternating and delivering direct current.

The ordinary rotary is a combined alternating-current motor and direct-current generator. It possesses certain characteristics of a motor, others of a generator, and still others that result from the combined action of the two. The characteristics of the synchronous motor will be considered in detail, then those of the direct-current generator, and, finally, those of their combination, or a rotary.

### A SYNCHRONOUS MOTOR

If two similar alternating-current machines be driven from the same counter-shaft at the same speed, and have the same field charge, they may be connected together in multiple in the same way that two similar direct-current machines running at the same speed and with equal field charges may be connected in multiple. If the belt be thrown off one of the machines, it will run as a motor, receiving its current from the other machine.

A motor that receives current from a supply circuit must conform to the characteristics of that circuit. A direct-current shunt motor, for example, must run under such conditions that the electromotive force of its armature is equal to the electromotive force of the supply circuit. This means that the speed, the field current and the work done must be mutually adjusted in such a way as to meet these conditions. If the field current be reduced, the speed will increase; if the load be increased, the speed will, in general, decrease. In like manner, a synchronous alternating-current motor must adapt itself to the conditions of the circuit, not only in electromotive force, but also in speed. It must run at a definite constant speed that is in a ratio to the speed of the

generator determined by the relative number of field poles in the two machines. A change in the field charge of a synchronous motor cannot be compensated for by a change in speed as is the case in a direct-current motor.

### EFFECT OF VARIATION IN FIELD STRENGTH

If the field current of the alternating-current motor be reduced, there can be no increase in speed, and there must necessarily be some other means for making the electromotive force of the motor correspond to that delivered by the generator. If the field charge of the motor be decreased, say, twenty per cent, it will be found that a very considerable current flows between the generator and the motor, possibly equal to the full-load current of the motor. This current is evidently a so-called "wattless" current, for, although it is apparently delivering the energy required by the motor at full load, it is actually delivering only sufficient energy to run it without load. The current flowing is, however, different from the current that flows when the motor is loaded under normal conditions, as the two currents do not have the same time relation to the electromotive force. In a loaded motor under normal conditions, the maximum current occurs at the time of maximum pressure, and zero current at the time of zero pressure. The position of the armature at the time of maximum current is shown in Figure 1. The armature conductors that are shown in black circles are those carrying current in one direction, while those shown as open circles are carrying current in the opposite direction. The armature is in a two-pole field, and the direction of the current in the field coils is represented in the same way, by dark and light circles.

When a motor with a low field current is connected with a circuit and receives a heavy armature current, this current does not flow simultaneously, or in phase, with the electromotive force. The maximum current occurs when the armature has revolved through ninety degrees (in which position the electromotive

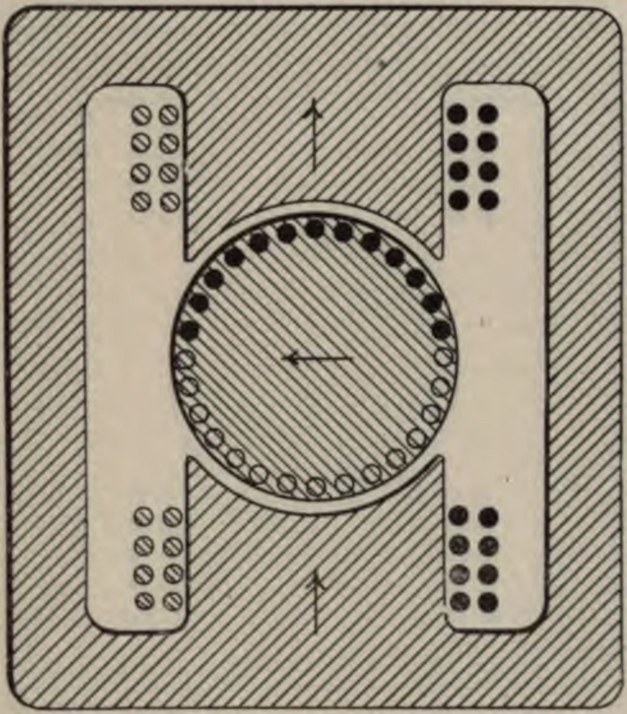


Fig. 1.

force generated is zero). The position of the armature at the time of maximum current is shown in Figure 2. It will be readily seen that in this position all the wires that carry current in one direction are on the same side of a line running through the middle of the field poles, and that the armature cur-

rent is in a position to directly aid the current in the field winding in its magnetizing effect, as is indicated by the arrows. This is equivalent to strengthening the field current. If the field current of the motor be reduced twenty per cent and the electromotive force of the circuit remain

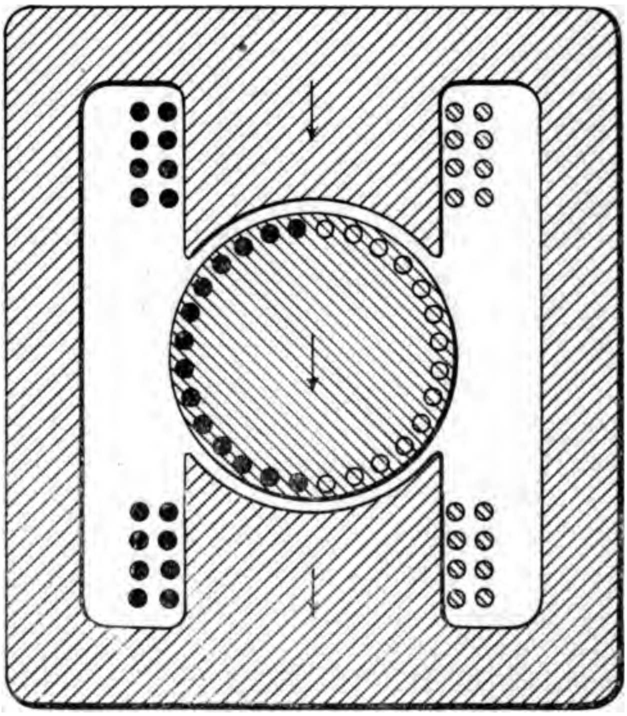


FIG. 2.

the same, then there will be sufficient current through the armature to make up for the twenty per cent reduction in the ampere turns in the field. In the generator, however, the position of the armature coils, when this current flows, is such that it acts against

the current in the field, thus reducing the effective magnetization. The position of the conductors at the time of maximum current is shown in Figure 3, in which the magnetizing effect of the current in the armature is seen to be directly opposed to that in the field. If the generator is large in comparison with

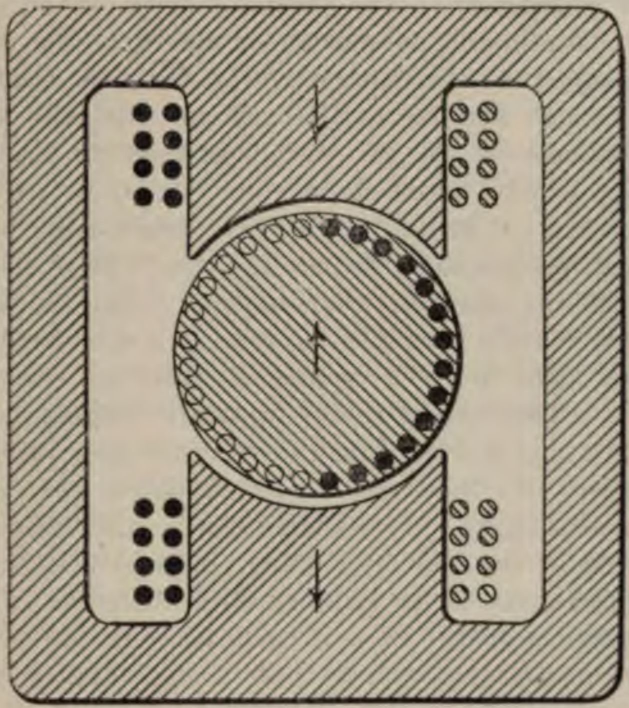


FIG. 3.

the size of the motor, the effect may be small; but if the motor be large, it may be considerable. If the two machines be of the same size and the electromotive force of the generator is 1,000 volts and that of the motor 800 volts before they are joined, then the resulting electromotive force, when the motor is con-

nected to the generator, will be about 900 volts. The current flowing through the two armatures will reduce the magnetization of the generator by opposing the ampere turns of the field, while in the motor the magnetization will be increased as the armature ampere turns assist those of the field. If the field current of the motor be increased so that its electromotive force before connection to the generator is, say, 1,200 volts, then a current will flow which demagnetizes the motor and magnetizes the generator. If the two machines be of equal size, so that a current produces about equal effects in the two machines, then the resulting pressure will be about 1,100 volts. It is, in fact, possible to run a motor without any field charge at all, but with an armature current sufficiently large to produce all the magnetization required. On the other hand, it is also possible to run a motor having a charged field from a generator that has no field charge. The current in the armature magnetizes the generator, while reducing the electromotive force of the motor. In this case, the electromotive force at the terminals is about half the electromotive force that there would be if the generator had its normal field charge.

When a motor is running with load, the current that delivers energy to it is in phase with the electromotive force, and produces only a slight effect upon the magnetizations and electromotive forces of the machines. When a motor is carrying load, the current to it increases if the field charge be too high or too low, as the electromotive force of the motor must be made equal to that of the circuit by an additional magnetizing current in the armature if the field current is not properly adjusted. These conditions are illustrated by the relative directions of the arrows in the first three figures.

In the illustration that has just been cited, it has been assumed that there is little or no resistance in the circuit joining the generator and motor. If, however, there is a considerable resistance in the circuit between the two machines, then the electromotive forces on their terminals will, in general, not be the same; that of the motor will usually be lower than that of the generator, as it is in direct-current circuits. It is possible, however, if there be inductive resistance in the circuit between the two machines, and if the field charge of the motor be increased, to make the electromotive force at the motor terminals equal to or greater than that at the generator. If the field current of the motor be increased as it is loaded, the electromotive force at the motor may be maintained constant at all loads or may be increased as the motor is loaded. On the other hand, if the field current of the motor be too low, there may be a greatly increased drop in generator and in transmission circuits. There is always a certain definite motor-field charge with which the motor will carry its load with a minimum current. Any variation in the field charge increases the current required by the motor, and this current, although it may be useful for regulating the electromotive force, causes increased heating and losses in the armature, and usually in the transmission circuits also.

### EFFECT OF VARIATION IN WAVE FORM

The electromotive force of a synchronous motor must be adapted to that of the circuit, not only in its average intensity, but also in its wave form. Two alternating-current machines may give equal electromotive forces of, say, 1,000 volts effective, although one has a maximum electromotive force of 1,410 volts

and the other of only 1,290 volts. At some other part of the wave, say, when the electromotive force of the first machine is 700 volts, that of the second machine may be greater, or 800 volts. The result is that at some instants the first machine would have an electromotive force over 100 volts higher than the second machine, and at other times the second machine would have an electromotive force higher than the first. If two such machines be run in synchronism, either both as generators, or one as a generator and the other as a motor, the difference between their electromotive forces at different times during each alternation gives an electromotive force for sending a current back and forth between the armatures. This electromotive force is one of a higher frequency than the normal frequency of the circuit—usually of three or five times its frequency—and it evidently cannot be avoided by changes in the field charges of the machines. This high-frequency current causes extra heating in armatures and transmission circuits, it reduces output, it causes increased drop and it contributes to "pumping."

The figures used in the foregoing example are taken from the published curve of the Niagara generators and the sinusoid. The result indicates what may be expected if a machine whose electromotive force wave is a sinusoid be connected with the Niagara circuits. This is illustrated in Figure 4, which shows the Niagara wave, the sinusoid and their difference, or the electromotive force which would send an idle current through the circuits. This is equal to about ten per cent of the normal electromotive force of the circuit.

## EFFECT OF VARIATION IN SPEED

It has been stated that the speeds of two machines that are run in synchronism is definitely fixed by their relative number of field poles. It is, however, not only essential that the two armatures make the same number of revolutions per minute, but that they be at the same speed at all times. If a generator that is

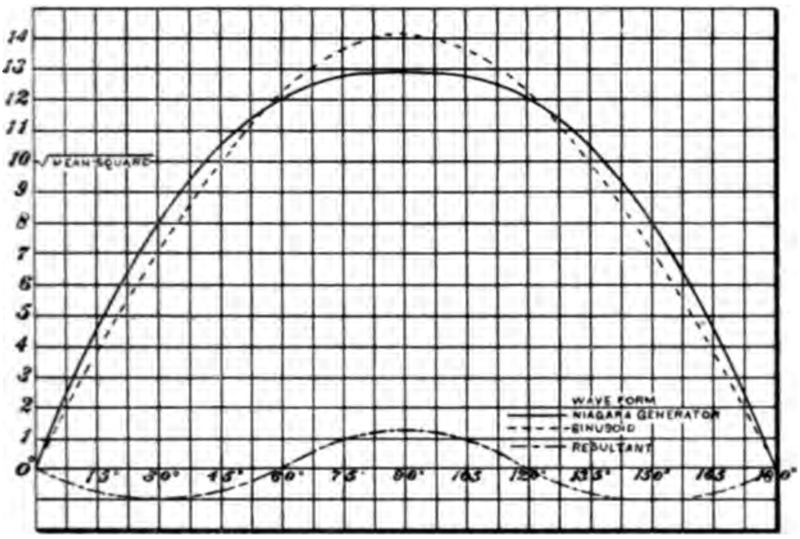



FIG. 4.

driven by an engine in which the speed varies in different parts of a revolution be connected in multiple with a second machine which is provided with a very heavy fly-wheel, so that it runs at practically uniform speed, then the phases of the two machines will at times be coincident, and at other times one machine may be in advance of or behind the other machine. The effect that a given difference of speed makes

upon the electric system depends largely upon the number of poles of the alternators. The variation in speed may be such that one armature is at times one one-hundredth of a revolution in advance and sometimes one one-hundredth of a revolution behind a second armature. If the machines have one hundred poles, then the electromotive force of the armature, which at one instant agreed in phase with the other, will, at the next instant, be of exactly the wrong phase, and a heavy current will flow through the armatures. If, however, the alternators be two-pole machines, then an advance of only one one-hundredth of a revolution of one armature ahead of the other will cause so trifling a difference in electromotive forces as to produce little or no appreciable effect.

A synchronous motor, especially if it is running at light load, tends to run at a uniform speed, as the revolving elements act as a fly-wheel. If the generator speed fluctuates, the electromotive force will sometimes be in advance and sometimes behind that of the motor, and the difference between the two will cause the current between the machines to fluctuate in strength, having its minimum when the electromotive forces of the two machines are directly opposite in phase, and a maximum when there is the greatest variation of this condition.

## "PUMPING" OF MOTORS

A synchronous motor that is connected to a circuit on which the conditions are fluctuating, tends to "pump," that is, the armature runs sometimes a little faster and sometimes a little slower than the generator, which usually causes a beating sound in the motor. This "pumping" or "hunting" action usually

results from some irregularity in the circuit by which the motor is supplied. This irregularity may be caused by variation either in speed or in electromotive force.

Variation in the speed of a generator tends to cause a corresponding variation in the speed of a synchronous motor. The motor cannot assume instantly the speed required by the new speed of the generator. When this increases, then the motor armature begins to increase in speed, but lags slightly. At this time the motor receives an increased current, because its armature is not in the normal position for the new frequency and because additional current is required for supplying the energy necessary for increasing the speed. The additional current produces a difference in the magnetization of the field, which must again be altered when the generator speed decreases below the average. The motor is therefore undergoing a slight variation in speed which does not exactly correspond to that of the generator, and it is undergoing changes in its magnetic field strength which cause it to receive from the circuit a fluctuating current, and this may in turn affect the electromotive force upon the circuit. The motor armature at certain times receives more than its average amount of energy from the circuit, and at other times may even return energy to the circuit. The electromotive force of the circuit is dependent, not upon the generator only, but upon the combined action of the generator and the motor, and the fluctuating current to the motor may produce a fluctuation in the electromotive force of the circuit. A fluctuating electromotive force upon a circuit, such as would cause a flickering or varying light in an incandescent lamp, will cause a motor to take an additional current,

either lagging or leading, at each variation. This, in general, tends to cause the motor armature to take a new position adapted to the electromotive force received at each instant, and therefore causes a varying or "pumping" action in the armature of the motor. Pumping may therefore be caused by variable speed in the generator or in other motors, or by variable electromotive force produced by the irregular action of the generator or of other motors.

### TORQUE AT LOW SPEEDS

A synchronous motor possesses but little torque at any speed except the synchronous speed. In general, it cannot be started except by the use of some auxiliary apparatus or at the expenditure of a heavy current in proportion to the torque developed. It must be connected to the circuit or "synchronized" when it has attained exactly the proper speed, when the electromotive force is equal to that of the circuit and has the right phase relation. When it is slightly below synchronism, its torque is greatly reduced. A momentary overload upon the motor may cause it to drop from synchronism. If the generator speed suddenly increase, as may be the case if a part of the load be thrown off a poorly regulated water-wheel, then, also, a synchronous motor which may remain upon the system must increase in speed almost instantly, which may be beyond the limit of the motor if it already be carrying normal load.

### RESUMÉ OF CHARACTERISTICS OF A SYNCHRONOUS MOTOR.

Among the characteristics of a synchronous motor that have a direct bearing upon its practical operation are the following:

An ordinary synchronous machine has small start-

ing torque, and requires either a heavy starting current or is started by auxiliary apparatus. A considerable amount of switchboard apparatus is required, and care must be used in connecting the machine to the circuit.

If there be a sudden increase in the generator speed, a synchronous motor may not be able to increase its speed quickly enough to prevent dropping from synchronism. The generator speed must be fairly uniform throughout each revolution, in order to prevent fluctuation in current, and pumping of synchronous motors.

If the electromotive force of the circuit be momentarily lowered (*e.g.*, by connecting a motor to the circuit when it is not in phase, or by overloading a motor and causing it to drop from synchronism, thus producing a heavy current), or if the electromotive force be cut off the circuit momentarily (*e.g.*, by switching the circuit from one dynamo to another), the synchronous motor may lose synchronism, and stop.

The field strength of the synchronous motor must be adapted to produce an electromotive force fairly approximating that of the circuit, or there may be an excessive current either leading or lagging. A lagging current produces a greatly increased drop in electromotive force in generator and transmission circuits. A leading current reduces drop in electromotive force, and neutralizes lagging current; if a synchronous motor and an induction motor be supplied by the same line, the leading current to one may neutralize the lagging current to the other, so that the line carries only the current necessary for transmitting energy to the motors.

The synchronous motor must have a wave form

In the early part of this paper, a machine was mentioned in which there were two windings; one for receiving alternating current for deriving energy as a motor, and the other for delivering direct current as a generator. If this armature has the same number of turns in the two windings, so that each alternating-current wire has a corresponding direct-current wire near it, we may examine the current flowing in the two wires at different times during the revolution of the armature, and then, by combining these currents, determine the current that would flow if the two windings were connected together, or if the two currents were flowing in one winding. At a given instant, a wire may be said to have two currents flowing in it; one due to the alternating circuit, and the other in connection with the direct-current circuit. The resulting or actual current will be the sum or difference of these two currents; the sum, if they flow in the same direction, and the difference, if in opposite directions. By determining the current that will flow in the successive positions of the armature during a revolution, we may compare the effect of the resulting current with that of the direct current alone, both in heating the armature conductors and in the effect upon the commutation.

## ALTERNATING CURRENT IN A ROTARY

An alternating current varies from zero to a maximum, having a particular value for each successive position in a revolution of the armature. In an armature revolving in a two-pole field, the current strengths for a number of positions of the armature are shown

in the accompanying Figure 5. The strength of current in the wires on the surface of the armature is indicated by the thickness of the circles representing the armature. The shaded portion indicates that the current is flowing in one direction, and the light portion, that the current is flowing in the opposite direction. The terminals are represented by black dots within the inner circle. The armature is assumed to be between two field poles, one directly above and the other directly below it; similar to those in Figure 1. The upper circle in the figure represents the armature in the position of zero electromotive force, and of zero current, also, when the electromotive force and current are of the same phase. The second circle shows the condition when the armature is moved through one-quarter of a right angle, or twenty-two and one-half degrees. The electromotive force and current are now thirty-eight per cent of the maximum that will be reached, and they are in one direction in the shaded section of the diagram, and in the opposite direction in the other half. The next circle shows the forty-five-degree position, in which the strength of the current is seventy-one per cent, and the fourth circle shows the condition when the next arc has been passed and the value is ninety-two per cent of its maximum. The fifth circle shows the ninety-degree position, in which electromotive force and current have reached the maximum values. This circle represents the same condition that is shown in Figure 1; the half of the armature nearest one pole is carrying current in one direction, while that nearest the other pole is carrying current in the opposite direction. A vertical line passing through the centre of the poles and the armature is seen to have an equal quantity of positive and of negative armature current on each side. As the result, the armature

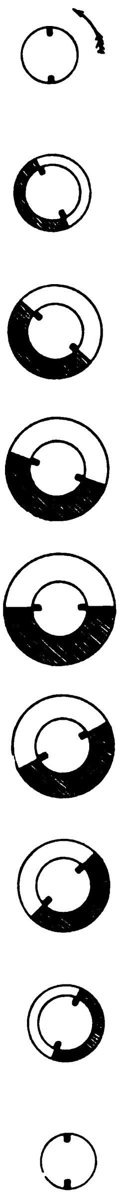


FIG. 5.
A.-C. SINGLE PHASE.

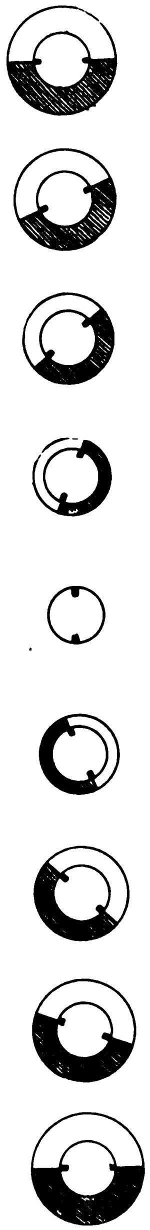


FIG. 6.
A.-C. 90° CIRCUITS.

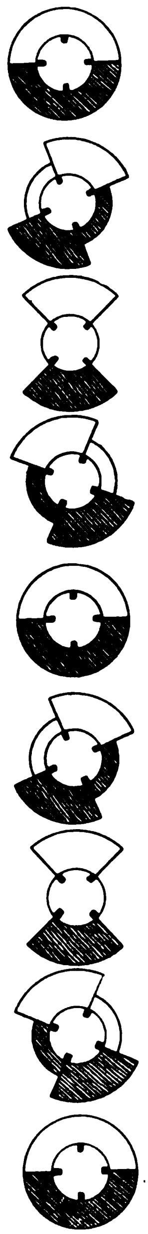


FIG. 7.
A.-C. TWO-PHASE.

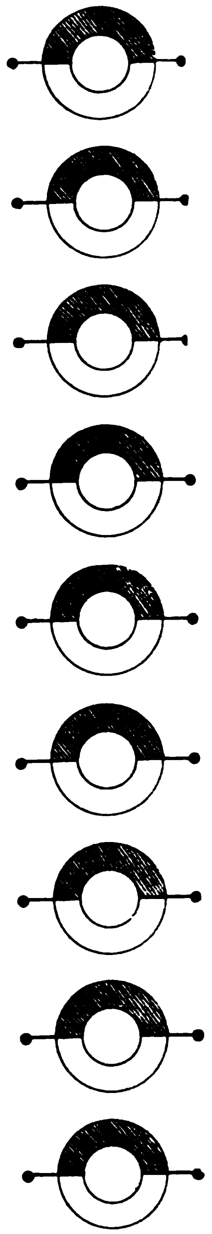


FIG. 8.
D.-C. GENERATOR.

currents do not have any effect in increasing or diminishing the magnetization of the fields. The conditions for the next quarter of a revolution are given in the lower circles, and the conditions in subsequent positions are simply a recurrence of the cycle that is shown in the nine circles given.

In a two-phase machine, the two electromotive forces are exactly similar, except that one occurs ninety degrees, or a quarter of a revolution, later than the other. The connections to the armature winding are exactly similar, except that one is made at a point ninety degrees from the other. The electromotive force and current in the second circuit are therefore identical with those that were in the first circuit a quarter of a revolution before. Diagrams for the second circuit are given in Figure 6. A comparison of Figure 5 and Figure 6 shows that the current in one is maximum when that in the other is zero.

If both circuits be derived from the same winding, then the two currents tend to flow in the same wires, and the actual current flowing is the resultant of the two. It will be the sum when the two currents are flowing in the same direction, and the difference when they are flowing in opposite directions. Combining Figures 5 and 6 in this way, Figure 7 is derived. The upper circle is seen to correspond exactly to that in Figure 6, as there is no current in Figure 5 at this time. The condition obtained at each quarter-revolution is the same, and is shown by the first, fifth and ninth circles. The current in the intermediate positions is seen to be different in different sections of the armature winding. In the forty-five-degree position, there are two quarters of the armature that have no current. It will be observed that the area in Figure 7 is considerably less than the sum of the areas in the two

figures representing the component currents. If the current in the armature wires of Figure 5 and of Figure 6 is represented by 1 in each case, then the current in the armature, when both circuits supply their currents from one winding, as in Figure 7, will not be equal to the sum of the two, or 2, but will be equal to 1.4.

A vertical line drawn through the nine circles in each of the three figures shows an equal area of shaded section and an equal area of light section on each side, so that there is no resultant effect on the magnetization of the fields.

### DIRECT CURRENT IN A ROTARY

The current in the armature of a direct-current machine, in which the brushes are set in the neutral position, having no lead, is shown in Figure 8. It will be noted that the current in all parts of the armature is of the same strength, and that the current occupies the same position with respect to the field poles, regardless of the angular position of any particular armature conductor. An armature that carries both the alternating current and the direct current in the same winding, will have a resultant current which is the sum of the two in those conductors in which the currents tend to flow in the same direction, and is the difference where the currents tend to flow in opposite directions. The successive circles in Figure 7 (which represent the current in a two-phase, alternating-current motor) and in Figure 8 (which represent the current in a direct-current dynamo) are combined to give the corresponding circles in Figure 9, which therefore represent the actual current in the armature conductors of a rotary

transformer in successive positions. It will be observed that in the first position there is no current in the armature. In this position, one of the alternating-current circuits is delivering no current, and the other is delivering its maximum current. The latter circuit is at this moment connected to those commutator bars on which the direct-current brushes are making contact, so that the current passes directly from the alternating-current circuit to the direct-current circuit, without traversing the armature winding. The same condition prevails when the armature has moved through ninety degrees, and the commutator bars to which the second circuit is connected have come under the direct-current brushes and the current in this alternating circuit has reached its maximum value. The continuous strength of the direct current is just equal to the maximum value of the alternating current. In intermediate positions of the armature, the current varies through a considerable range, as is indicated by the intermediate circles. The figures clearly indicate that the current in the armature conductors is less when the machine is used as a rotary transformer than it is when used as a direct-current generator. The armature can deliver about sixty per cent more direct current, with the same heating effect, as a rotary transformer than it can as a direct-current generator. An inspection of the circles in the figure representing the rotary shows that the current in the armature conductors that are directly in front of the field poles—that is, on the upper and lower portions of the circles—is very much less than it is in the figure representing the direct-current generator. As a consequence, the distortion of the field magnetism is very much reduced, and the conditions for commutation are therefore greatly improved.

The loss due to magnetic induction in the teeth of an armature depends, other things being equal, upon the maximum magnetization. In a machine in which the field is very much distorted, being weak at one side of the pole and strong at the other, the iron loss is much increased over what it would be if there were the same total magnetism from the field pole, but evenly distributed across the pole face. The losses arising from field distortion are very small in the rotary, as there is so little distortion.

## THE INDUCTION ROTARY

It has been stated that if the field current of a synchronous machine be reduced, there will be an increased armature current which can compensate for the decreased field current and maintain a constant magnetization. In a suitably-designed machine, the field current may be reduced to zero, and the whole magnetization derived from the armature current. The current in this case, as has been shown in Figure 2, has its maximum value in quadrature, or ninety degrees from the maximum electromotive force. A single-phase armature, in which the current is in phase with the electromotive force, is represented in Figure 5. If the current lag ninety degrees, then the relation of currents may be seen in Figure 10, in which the current has its maximum value in a position ninety degrees later than that at which the maximum value occurs in Figure 5. It will readily be seen that in Figure 10 the current represented by the shaded portion of the diagram is almost entirely on one side of the vertical line, so that the currents in the armature are in proper position for magnetizing the field. The current in the armature of a two-phase motor which

is magnetized by the armature currents is shown in Figure 11. It will be noted that the current is distributed in the same way as in Figure 7, which represents a two-phase motor in which the currents are in phase with the electromotive forces, except that the corresponding currents occur when the armature is moved through ninety degrees. The position of the current in the armature is such that the shaded portion lies almost entirely on one side of the vertical line passing through the centre of the shaft and the field poles, and consequently is in the most favorable position for magnetizing the fields. If such an induction motor be provided with a commutator, direct current may be delivered, and the action of the machine will be exactly the same as if it were excited by current in a field winding instead of current in the armature winding. For simplicity, we may assume that there are two windings on the armature—one for carrying the magnetizing current, and the other for receiving the alternating current which supplies direct current from the commutator, as has been shown in the former figures. When there is but one winding, then there is a resultant current in the armature, which may be found by combining the current that magnetizes the motor and that which contributes to the supply of direct current, adding the two when they are flowing in the same direction, and taking their difference when they are flowing in opposite directions. The magnetizing effect must be practically constant at all times. The current in phase with the electromotive force, which, therefore, supplies energy, which is in turn delivered to the direct-current circuit, varies with the load. The resultant current therefore varies with the load. It will be found that the alternating current to the motor, as well as the currents in the armature wind-

ings, is not equal to the arithmetical sum of the magnetizing current that can be measured at no load and the current that is useful in supplying the direct-current circuit. The resultant current is less than the sum, and the difference becomes greater and greater as the motor is loaded.

### EFFECT OF CHANGE OF LEAD

An interesting and important variation is produced when the angular position or lead of the direct-current brushes is changed. Omitting for the present the lagging or magnetizing current, and considering only the current which is in phase with the electromotive force, and supplies energy for the direct current, the distribution of current with no lead is shown in Figure 9, and with backward lead of twenty-two and one-half degrees, is shown in Figure 12. The currents in these figures are similar, except in the arcs through which the brushes have been moved from their neutral position. In Figure 9, it was noted that there was no magnetizing effect produced in the field by the armature current. In Figure 12, it will be observed that the currents in the sections through which the brushes have been moved are so located as to produce considerable magnetizing effect, as there is a current in one direction on one side of the armature, and in the other direction on the other side of the armature. When the brushes have this position, the current in the armature resulting from the currents that are in phase with their electromotive forces, and which supply the direct current, produces a magnetizing effect which will therefore reduce the amount of magnetizing current necessary from other sources. In an induction rotary in which the brushes are given

a backward lead, this effect can be secured, thus requiring a less amount of lagging current, or current that

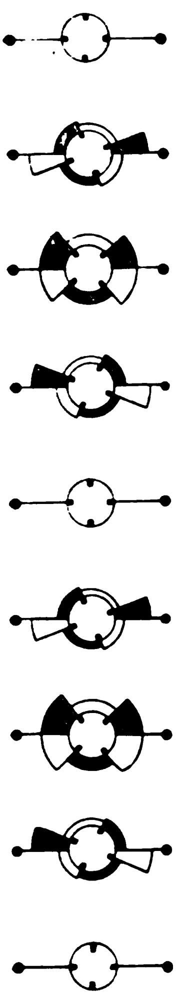


Fig. 9.
Rotary.

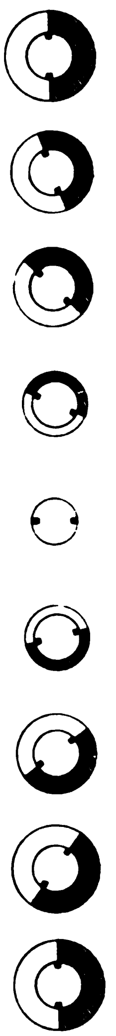


Fig. 10.
A.-C. Single-Phase
90° Lag.

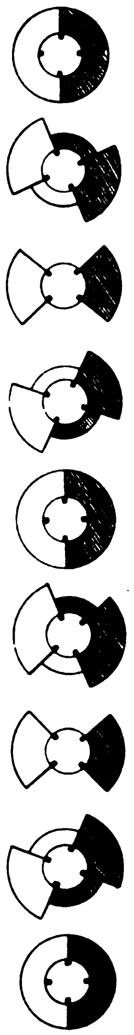


Fig. 11.
A.-C. Two-Phase
90° Lag.

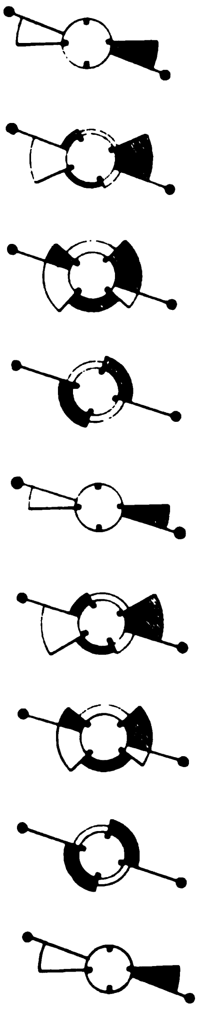


Fig. 12.
Rotary Backward Lead.

is ninety degrees behind its electromotive force, when the machine is loaded. If we assume that the mag-

netizing current in the armature is flowing in one winding and the current for supplying the direct-current circuits in another winding, we shall find that the current in the magnetizing winding decreases as the machine is loaded. Moreover, this magnetizing current can be varied by varying the lead of the direct-current brushes. With the brushes at the no-load or neutral position, the magnetizing current would be found to be practically constant whatever the load. As stated above, if the brushes are given a backward lead, the magnetizing current will decrease, while, if they are given a forward lead, it will increase.

This effect is useful in regulating the voltage of the direct current delivered by the induction rotary. At no load, the lagging or magnetizing current is, as is well known, of a character to produce a considerable drop or lowering of voltage in the generator and transmission apparatus, and in the rotary itself, especially if they have considerable self-induction. The drop produced by a lagging current is considerably greater than that produced by a non-lagging current of the same strength. If, therefore, this lagging component of the current to a rotary be diminished, the drop in the alternating-current circuit will be considerably reduced. This is effected by giving a backward lead to the brushes in the manner just explained. As the rotary is loaded, the magnetizing current decreases, which produces less drop and, therefore, a higher electromotive force on the direct-current circuit than there would be if the brushes were kept in their neutral position. The reduction in the magnetizing current also decreases the total current to the rotary when it is carrying load, and consequently increases the power factor of the system.

The induction rotary possesses essentially the same

characteristics as the rotary with excited field in the increase of output that can be obtained from an armature of given size over that which can be obtained from a direct-current machine. The induction rotary possesses great superiority over the rotary with excited field in its facility for adapting itself to the conditions of the circuit. A synchronous machine, as has been pointed out, must be adapted to the circuit that supplies it, in wave form and in electromotive force. A machine with excited fields possesses its own definite characteristics, its wave form being dependent on its mechanical proportions, and its electromotive force being dependent upon its exciting current, which is under the adjustment of an operator. Such a machine is an independent unit, impressing its own characteristics of wave form and electromotive force upon the system to which it is connected.

An induction machine has no characteristic wave form or electromotive force. In these respects, it is not active, but passive. It receives its magnetizing current from the alternating circuit in the same way that an ordinary transformer or converter does. The current flows in just sufficient amount to suitably magnetize the machine for producing an electromotive force that in amount and wave form is exactly adapted to the circuit to which it is connected. In these regards, the induction rotary possesses the same marked advantages over the rotary with excited fields that the induction motor possesses over the synchronous motor with excited field.

The induction rotary has sufficient starting torque to be self-starting. The rotary with excited field is, in general, capable of self-starting, but under conditions that are not so favorable to the circuit as the induction rotary, as the latter requires much less starting current.

When the conditions of speed or electromotive force on a circuit are fluctuating, the induction rotary is much less liable to be affected than the rotary with excited field. The action of the induction rotary is,

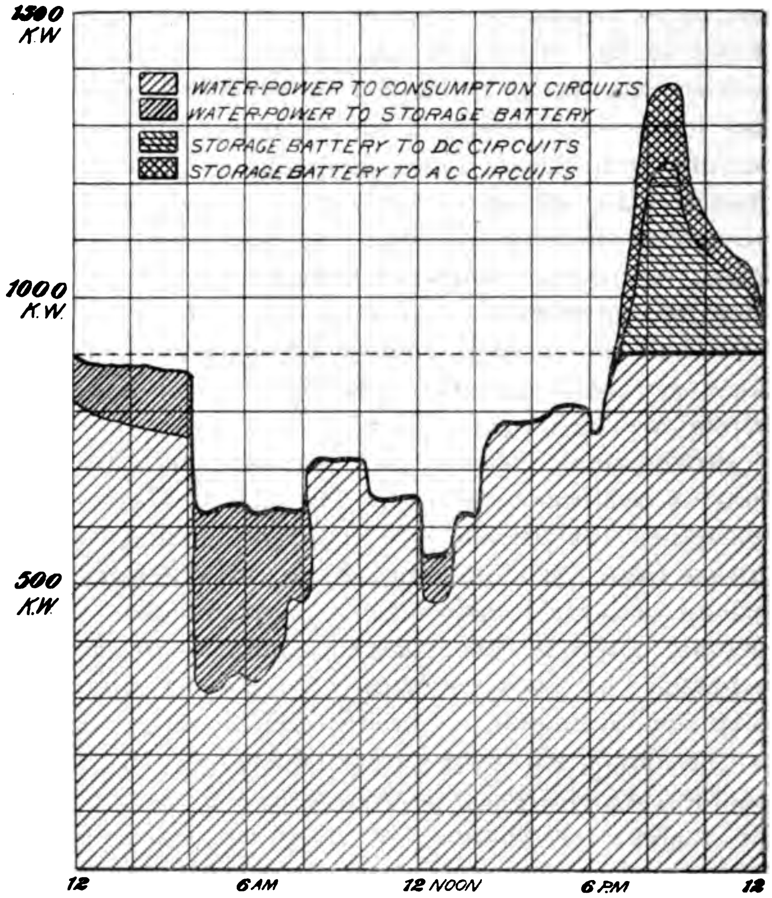



FIG. 13.

in a measure, pliable and elastic, which adapts it much more readily to slight changes than its rigid and exacting prototype. In fact, in a certain test, a rotary transformer of the direct-current field type was so

sensitive to variations in the circuit that it could not be operated from a commercial circuit, but was able to run with perfect steadiness as an inducton rotary when its field circuit was open. The machine was not properly proportioned for running continuously as an induction rotary, as the exciting current was excessive. This, however, could be modified by making slight changes in the design of the machine, adapting it for operation as an induction rotary.

I have seen two induction rotaries running in multiple, which divided the load in any ratio that was desired, depending on the relative lead of the brushes. The switch of either machine could be opened, throwing double load on the other machine; and this load could, in turn, be thrown off instantly or thrown on instantly without producing any noticeable sparking at the brushes. The rotaries were tested at widely different electromotive forces and on circuits having different wave forms, and showed themselves perfectly adapted for meeting a very wide range of conditions. The induction rotary is best suited to circuits of a low number of alternations, and, except in small sizes, is not well adapted for 7,200 alternations or sixty-cycle circuits.

### REGULATION OF VOLTAGE

The electromotive force at the commutator of a rotary is related to that of the alternating current at the collector rings by a definite and practically constant ratio. A commutator electromotive force of one hundred volts requires an alternating electromotive force of seventy to eighty volts, depending upon the wave form. A variation of the direct-current voltage, therefore, requires a corresponding variation in the alternating-current voltage supplied. This may be varied,

either by changes in the generator or in the transmission apparatus between generator and rotary; or it may be made by changes in the rotary itself, either increasing the field strength or otherwise.

(1). The voltage may be varied by varying the electromotive force upon the generator, consequently increasing the electromotive force throughout the system. This is, in general, applicable only when a generator supplies one rotary alone.

(2). The voltage may be varied by changes in the ratio of the windings of transformers that are placed between the generator and the rotary. This regulation may be done in one of several ways:

(a). Loops may be brought out from the transformer for supplying voltages differing by steps of, say, ten per cent, and the rotary, before being started, may be so connected that it receives one of these voltages, there being no provision for changing the voltage while the rotary is running.

(b). The lowering transformer which supplies current to the rotary may be made with an adjustable or moving secondary, by which the relation between the primary and secondary coils is varied, effecting gradual changes in the electromotive force delivered to the rotary.

(c). The transformers may be provided with many loops connected to a switching device or controller, by which the electromotive force of each phase can be raised or lowered by, say, one-per-cent steps. In such a regulator, the circuits may be so arranged that one circuit is switched at a time, the rotary being operated as single-phase during the instant of switching over.

(3). An auxiliary machine may be placed on the shaft of the rotary or be driven by a separate motor.

This machine may be excited by the direct current from the rotary. Such an auxiliary generator or booster will have an electromotive force dependent upon its field strength, and may therefore be used for increasing the electromotive force as the load increases. It may be wound for alternating current and increase the electromotive force of the alternating circuit before it reaches the rotary, or it may be wound as a direct-current machine and add to the electromotive force delivered by the commutator of the rotary.

(4). The field strength of the rotary may be increased as the load increases, by compounding it in the same way that an ordinary direct-current machine is compounded. A low field charge at light load will cause a lagging current to flow, which will cause a drop in electromotive force if there be self-induction in the circuit. If the field current be increased, the lagging current will become less, and the drop will become less. A strong field will increase the electromotive force at the alternating-current end of the rotary above that which the circuit would otherwise deliver. This electromotive force may be kept the same at full load as it is at no load, or may be made to increase so that the alternating electromotive force at the rotary is greater at full load than at no load. In this method of operating, the current to the motor is usually a lagging or a leading current, and involves a power factor less than unity.

(5). In the induction rotary in which there is no direct-current field charge, the brushes may be given a backward lead, so that the direct current flowing in the armature replaces in magnetizing effect a portion of the lagging alternating current that magnetizes the machine at no load, and therefore reduces the amount

of lagging current supplied to the machine. This causes a less drop in generator and transmission circuits, so that there may be an increasing electromotive force between no load and full load.

## SUMMARY OF CHARACTERISTICS OF A ROTARY

A rotary acts both as an alternating-current motor and as a direct-current generator, and has the following characteristics:

(1). The machine is similar to an ordinary synchronous motor in its dependence upon the wave form and the electromotive force of the circuit to which it is connected, and upon the speed of the generator. A circuit that is variable in speed or in electromotive force may produce an unstable condition in a rotary, which tends to produce a mechanical oscillation or "pumping" action. This may be so slight as to cause no practical inconvenience, or it may be sufficient to cause periodic sparking of an injurious amount or a fluctuation in the electromotive force delivered, or it may be so great as to prevent the mechanical running of the machine.

(2). Rotaries are of two types: the direct-current field rotary and the induction rotary. The former type requires a much more careful adaptation to the circuit on which it is to be operated, and is much more sensitive and liable to disturbance in its operation than the induction rotary, although its successful operation in service proves that there is no question as to its commercial success. The induction rotary is a simpler and cheaper machine to construct and to operate; it possesses many advantages over the first type, and can, in general, meet all conditions more successfully, except those requiring considerable com-

pounding, especially with variable loads, and for operation of large sizes on high-alternation circuits.

(3). With the same output, the loss in the armature conductors of a rotary is less than it is in a direct-current machine; therefore, if the loss be kept the same, the output of a machine of given size can be increased. In a three-phase rotary, the output can be increased about thirty per cent, and in a two-phase rotary about sixty per cent, over the output as a direct-current machine; the loss being the same, and the efficiency consequently increased.

(4). The current in the armature of a rotary is distributed in such a way that there is little current in the conductors in front of the pole faces, thus avoiding the distortion of the field magnetism that is common in direct-current machines. This enables the machine to commutate a larger current, and renders it less sensitive to changes in lead of the brushes. It also reduces the loss in the armature iron.

(5). The electromotive force delivered by a rotary may be varied over a wide range by adjusting the electromotive force delivered to it, and it may be varied to a slight extent through proper compounding of the field or setting of the brushes.

(6). The electromotive force for which a rotary can be constructed depends upon its frequency; the higher the frequency, the greater the number of poles required for a given speed. On a 3,000-alternation circuit, a machine will run at 750 revolutions if it has four poles, while on a 7,200-alternation circuit, there must be ten poles for a speed of 720 revolutions. The brushes on one machine rest on the commutator at four points, dividing it into quadrants; while on the other machine they divide it into ten parts, so that if the commutators be of the same diameter, the

distance between brushes is much less in the high-alternation machine. The number of commutator bars, and, consequently, the electromotive force that can be commutated, is also less. As the size of the commutator is limited by the peripheral speed, it is evident that the greater the number of poles, the less is the electromotive force for which a machine can be built. If the number of alternations remains the same, it is not possible to increase the number of commutator bars by changing the number of poles; for if the number of poles be made half as great, then the number of brush-holders is correspondingly reduced; but the diameter of the commutator must also be reduced in the same proportion in order to maintain the same peripheral speed. This makes the distance between neutral points on the commutator the same with the fewer poles that it was with the greater number.

Mr. Clay: Mr. President, I move that the thanks of this association be tendered to Mr. Scott for his very able, interesting and instructive paper.

Mr. Ayer: I second the motion.

Carried.

The President: I declare the motion carried. Mr. Scott, I have much pleasure in tendering to you the thanks of the association for your paper.

The President: The next item on the programme is the deferred report of the Committee on Standard Candle Power of Incandescent Lamps, Dr. Louis Bell, Chairman.

Mr. Ayer: Mr. President, in the absence of Dr. Bell, as chairman of the committee, I will read the report.

# REPORT OF COMMITTEE ON STANDARD CANDLE POWER OF INCANDESCENT LAMPS

The task that your committee undertook was to draw up a suitable specification for a standard incandescent lamp, and to devise a proper method for the commercial application of this standard.

This problem divides itself into the three following heads:

I. The determination of a standard of light and the method of applying it under commercial conditions.

II. The specification of a direct, simple and rapid method by which the members of this association, and other users of incandescent lamps, can apply such a standard of light to the testing of commercial incandescent lamps.

III. The specification of a normal standard of luminosity, to which commercial incandescent lamps shall adhere.

The first task was the selection of a primary standard of light to serve as the basis of operations, proper apparatus, and methods for its utilization for the purpose in hand. There are in use as primary standards of light a considerable variety of sources of light, to wit: Two standard candles—English and German; three standard lamps burning definite substances under definite conditions—the Carcel lamp, the Harcourt pentane lamp and the Hefner-Alteneck amyl-acetate lamp; one standard gas light—the

Methuen, and, finally, the Violle platinum standard—one square centimeter of platinum at its point of solidification. In addition, there are more or less desirable forms of photometer.

Even assuming a standard light and method, the comparison of an incandescent lamp with it may be under all sorts of conditions and at all sorts of angles.

In this state of affairs, your committee requested the co-operation of the American Institute of Electrical Engineers, and, through the courtesy of the Council, the problem was referred to the Committee on Units and Standards. The following determinations were presented by that body, in which your committee, having discussed the matter in joint conference, concurs:

A. The Hefner-Alteneck amyl-acetate lamp is recommended as the primary standard, it being, on the whole, the most reliable and uniform. It possesses the additional advantages of having been subjected to most exhaustive tests, to determine its behavior under different conditions, and of being readily obtainable in standard form from an authoritative source.

B. The Lummer-Brodheim photometer screen is recommended, as being well suited, from its great sensitiveness, to exact and refined determinations.

C. It is recommended that, in testing incandescent lamps by these means, the lamps be revolved on a central axis at the rate of about two revolutions per second. This process gives the mean luminosity in the plane of revolution without a multiplicity of measurements.

D. It is recommended that, in so far as the conditions of commercial testing allow, the normal stand-

ard incandescent lamp be rated in terms of its mean spherical candle power.

It now became the task of your committee to put these recommendations in such concrete form as would most directly render them useful to the members of this association and others interested in the everyday work of testing lamps.

For easy and accurate photometric work it is highly desirable that the lights compared should be of nearly equal color and intensity. The Hefner–Alteneck standard is of about one candle power, and has a slight orange cast, so that, while giving very precise results in careful hands, it is somewhat inconvenient for rapid comparisons. Your committee therefore recommend the use of the Hefner–Alteneck standard to prepare secondary standards for commercial use. These standards should be incandescent lamps, of uniform shape, construction and character, standardized with the greatest attainable exactness, and suitable for direct comparison with commercial lamps. In testing lamps by these secondary standards, the above-mentioned photometer screen being rather difficult of manipulation for rapid work, we recommend a form of photometer designed specifically for use in connection with a standard method of measurement hereinafter described.

To avoid the complication incident to spinning both the secondary standard and the lamp being tested, we advise placing on the socket of the secondary standard a defining mark showing the direction in which the directly-given light is exactly equal to the mean determined by spinning. By placing this mark toward the photometer screen and in the plane of the photometer bar, only the lamp under test need be spun.

It is obvious to your committee that the common rating of incandescent lamps by their mean horizontal candle power is objectionable, and should not be continued. In the first place, as incandescent lamps and other lights are practically placed, one is invariably below them, and hence, if their axes are vertical, below the principal plane of illumination. If their axes are tilted, we still get the full advantage of but a portion of this principal plane. Secondly, it is, unfortunately, only too easy to produce lamps in which the maximum light is not only in the horizontal plane, but which in all other directions give decidedly poor illumination. Such lamps are practically of far less than their rated candle power.

The ideal distribution of light would be a uniform spherical one, except in so far as the socket might prevent. In any ordinary position, such a lamp would distribute at least half its light uniformly downward, where it would be of most use. In practice, this cannot be readily obtained, but it is easy to produce a lamp that will give a fairly uniform distribution, at least below the plane of the socket when the socket is uppermost.

Rating lamps by mean spherical candle power will strongly tend to produce lamps having such a distribution. The measurement of mean spherical candle power is, however, a very troublesome matter, and, even under the most favorable circumstances, is a slow process, not readily applied to commercial testing.

Your committee, therefore, cast about for a practical method of testing, such as would insure a good and useful distribution of light and would be easy to apply. In other words, how shall the light of a lamp be measured so as to rate it as nearly as practicable on its useful distribution of light?

After looking into the distribution of light actually given by commercial lamps, your committee believe that the light given half way between the vertical and horizontal planes forms the best simple criterion available. This can readily be measured by rotating the lamp socket down, with its axis inclined forty-five degrees toward the photometer screen and in the plane of the photometer bar. This measurement gives a fair mean between the horizontal and the vertical illumination, and in most commercial lamps is a tolerable approximation to the mean spherical candle power. Furthermore, it insures a good downward distribution of light, even in a lamp designed to meet this particular method of measurement.

Your committee is fully aware that no simple measurement can truly calculate the effective luminosity of all forms of lamp, but, recognizing that in the rapid commercial testing of lamps a single simple measurement is highly important, strongly recommends this one as most nearly meeting the necessary conditions.

By this process of simplification, we have reduced the measurement to be made by the user of incandescent lamps to the comparison of two nearly equal and similar lamps, of which only the lamp under test has to be revolved.

Furthermore, in much commercial testing it is not necessary accurately to determine the candle power of the lamp under test. In most cases it is sufficient to determine that it falls within certain definite limits prescribed for the normal standard lamp. Hence, it will generally not be necessary to make an exact setting of the photometer screen, but merely to observe the conditions existing when the screen is resting against stops in two fixed positions, one correspond-

ing to the minimum permissible candle power of the lamp under test, the other to the maximum.

The actual process of testing would then be as follows:

Having placed the standard lamp in its marked position, and adjusted the voltage to its normal value, the observer would then place the lamp to be tested in its socket and spin it, having first pushed the photometer screen against one stop. If the candle power was all right on this test, he would pull the screen against the other stop and look again. The whole process need not take over fifteen to thirty seconds, according to the skill of the operator, and would show definitely whether or not the lamp fell within the standard limits. Your committee will in due season place in the hands of the secretary a full specification for the making and use of a simple photometer, designed to be used in the manner just indicated.

We now reach the third portion of our task, to wit., the definition of a normal standard to which commercial incandescent lamps should conform. At present, there is much confusion on this subject, and we feel that it must be reduced to terms at least simple and definite.

It seems to your committee inadvisable at present to complicate the situation by introducing considerations of efficiency, life, and variations of candle power with life. Efficiency—the candle power being known—is settled at once by the application of a voltmeter and ammeter, and the matter of life may properly be left to the natural course of competition for settlement. Variation of luminosity with time is a matter of importance, and, after a general and uniform standard has been promulgated, may properly be

considered. For the present, however, your committee is of the opinion that attention should be confined to the adoption of a standard specification for light alone, and the production of suitable apparatus for testing the fulfilment of this specification. To this end, we believe it best to rate commercial incandescent lamps by the illumination obtained when the lamp is spun with its tip inclined forty-five degrees from the vertical, toward the line of observation, and to specify the rating in candle power, this being the most familiar measure of light, and definitely legalized in some States. The ratio between the English standard candle and the Hefner–Alteneck lamp has been accurately determined by several experimenters, so that it is easy to pass from the latter to the former, thus avoiding extreme unsteadiness when used directly.

As a matter of manufacture it is very difficult to produce a lamp of a given voltage for an exact specified candle power. Hence, certain limits must be set rather than a certain definite candle power, and these limits should be so drawn as to meet the conditions of manufacture and to insure a reasonably close accordance with the rated intensity. For an incandescent lamp rated at sixteen candle power (oblique zonal, as above indicated), fifteen candle power for the minimum and seventeen candle power for the maximum afford limits fair to all parties concerned, and these your committee recommends.

As to the method of procuring and distributing the secondary standards to be used with the photometric method already outlined, the following is desirable: Incandescent lamps of uniform shapes and in standard sockets, with filaments uniform in shape and section, in all respects unmarked, should be furnished by

the lamp manufacturers to the standardizing committee. These lamps should then be properly aged and standardized at such voltage as may give precisely sixteen candle power with the greatest possible precision, marked on the sockets with a reference line, numbered, certified and dated. They should then be turned over to the secretary for distribution at a price covering the cost of standardization and handling.

Your committee therefore recommends:

1. That the standard sixteen-candle-power incandescent lamp shall be a lamp which, when measured in rotation at about the rate of 180 revolutions per minute, with its axis inclined forty-five degrees, as herein specified, shall give not less than fourteen and one-half and not more than seventeen and one-half candle power, and that every ten lamps shall average between fifteen and seventeen candle power.

2. That your committee shall be empowered to make suitable provision, with the consent of the executive committee, for the production of the secondary standards, and to request the co-operation of the American Institute of Electrical Engineers in the formation of a non-partisan committee to supervise and certify said lamps.

3. That the secretary be directed to undertake, under the direction of your committee, the procuring of lamps for standardization, their distribution when standardized, and the preparation and distribution of the specifications of your committee for a standard form of photometer and a standard method of employing it.

Respectfully submitted,

LOUIS BELL, Chairman;
JAS. I. AYER,
L. A. FERGUSON,
*Committee.*

DISCUSSION

Mr. Ayer: I will state, in connection with this report, that the theory is to have a form of incandescent lamp specified that may be produced by the different manufacturers, so made that it would be without identification marks, and submitted and sent to the secretary; these to be turned over in bulk to some college testing laboratory, where the testing process should be under the supervision of this non-partisan committee of the association and of the Institute of Electrical Engineers. The Institute of Electrical Engineers was loath to mix up with any commercial transaction of this kind, but, seeing the importance of securing some standard, and knowing of the plan and suggestion that was offered whereby they could co-operate, they have admitted their willingness to take part in it in this manner. As to the efficiency of the photometer—the arrangement of it—it is proposed to make a specification of a photometer, which would cost little, which would be handed over to different manufacturers, and when made would be submitted to this committee for its approval as to being mechanically well made and suitable for the purpose. This puts the central station man in a position to have a photometer that can be easily operated by any ordinarily intelligent station employé, easily determining the initial candle power of the lamps compared; and if, later on, he cares to get life tests and others, it makes it extremely simple to do so. Half a dozen lamps of as many manufacturers, or any number of manufacturers, could be placed on the rack in the station, subject to these working conditions, at intervals of time after the first test, starting at the same initial candle power within the limits mentioned, and could be compared for life and quality as to the

time limit. That is, you can get down ultimately to putting the central station man in the position of being able to know what the candle-power value of his lamps is. (Applause.)

THE PRESIDENT: Gentlemen, you have heard the report of this committee. The report is now before you for discussion. It is a very important one, and should be considered and discussed very carefully, and the association can then take whatever action it in its wisdom deems best.

MR. GARDENER: I should like to ask if the report has been printed.

MR. AYER: It will be a part of the proceedings.

MR. GARDENER: I move that it be printed and sent to the members of the association. I think it is a very valuable report, and I should like to study it more at leisure.

MR. STETSON: I did not catch the idea whether the base of the lamp, on forty-five degrees, was the orifice or the dome.

MR. AYER: The dome would be inclined toward the screen, but the centre of the filament would be in the vertical axis; that is, as shown by a plumb bob, a line hanging down, getting the definite position of the screen or its position for the standard of the lamp—the position of the lamp. Nothing will be a standard vertical except having a vertical line pass through the socket. In this case it would pass through the centre of the lamp, which would indicate the average of the candle power of the lamp if there were two standards actually being compared that were both accurate. You would then get a perfect measurement. It will lean toward it, but it won't lean over the line. If it were placed over, we will say, a sixteen-candle-power or a standard, it would not lean over enough to run backward.

Mr. Stetson: You want the line of sight to run through the centre of the strongest illuminant quality of the lamp?

Mr. Ayer: Well, through the point where useful illumination is developed, and where we want the lamp at its best for commercial purposes. The theory is, as everyone realizes, that a lamp gives its most valuable results in its lower hemisphere; the lower half of it is what we use for illumination. We do not care much about the upper half, up near the socket. Now, if the lamps in this test can be improved in their illuminating qualities, they doubtless will be, so that you will get a stronger and better luminosity in the distribution of light in the usual and natural positions in which lamps are used than you can get with other methods of measurement.

Mr. Stetson: You recommend that the bar supporting the lamp might have a motion that would drop it into the strongest luminous position? Would that be so?

Mr. Ayer: Not to drop it. If reached, it would be a fixed device, having a socket that would be spun so that you would revolve it, but at an angle of forty-five degrees. If measured horizontally, candle power may give you a very false value of a lamp. It would show strongest in that position, while in this position it would not be so strong, with the same lamp, with your arrangement of filaments so as to get a fine strength of light in one single position, particularly in the horizontal measurement, it would not be nearly so effective as lamps that would not measure as much in the horizontal plane.

Mr. Stetson: That will probably be shown in the sketches and in the description of the photometer contained in the report.

MR. AYER: Yes; that will be fully set forth,—the detail working. It simplifies the method of finding out what you have and what you use; and if this report meets with your approval, I want some member of the association to move that its recommendations be adopted. The report calls for further action on the part of this committee for carrying this out. The report is worthless if it is simply accepted and filed, because it means nothing so far as it has gone. Here is a recommendation of the standard. the thing that we were asked last year to do; and I can assure you there has been a lot of work to it. The deductions are all right. They are not oppressive to the lamp manufacturers, but they are certain to improve the standard quality of lamps, to enable the station man to put out the poor lamps, and to benefit, probably, the better class of manufacturers, because it says, "We are trying to give you a better profit;" and it is the consensus of opinion of the representative manufacturers here that this is likely to reach that result.

MR. STETSON: I should think you were pretty liberal toward the lamp people in your arrangement of fifteen and one-half to seventeen. I do not wish to throw that out as a criticism, because you are very much more thoroughly posted than I, but simply in the way of discussion of the subject. I know that a slight rise in the candle power of a lamp sends up your area of useful work, your hour candle-power capacity. You want to be careful not to get it too high, because you may have a lamp that will make that area yet be a very short lamp.

MR. INSULL: Do I understand that you want a resolution adopting the recommendations of the committee? Don't you want added to it a continuation of the committee, or is this a standing committee?

MR. AYER: I think it is considered a standing committee until its duties have been completed. That is customary in the association, like our committee on rules for wiring, and all that sort of thing. They are considered standing committees, I think, and are not discharged unless the report completely covers the work.

MR. INSULL: I move a resolution that the report of the committee be accepted, and that their recommendations be adopted by the association, and, if necessary, that the committee be continued.

MR. WILMERDING: I just want to ask for information,—from my recollection, when this committee was appointed it seems to me that there was a provision in the resolution that the Society of Electrical Engineers should also be consulted.

MR. AYER: The report calls for that; that is part of the whole scheme.

MR. WILMERDING: Do I understand that they concur in the report?

MR. AYER: Well, not in our report, but they make recommendations, upon which this report is based, as to determining the standard. They have fixed it, and we have made the report in accordance with their suggestion for a primary standard.

MR. RHOTEHAMEL: I understood that the object of this resolution was to get at some standard light. and that was to be about the extent of the present provision; so that when a sixteen-candle-power lamp was ordered from any of the different manufacturers, we should have a means of obtaining from the people holding the standard, a standard from which we were to reckon our light. I have not heard all of the discussion, and I do not know whether the report goes further in regard to the incandescent.

THE PRESIDENT: Mr. Rhotehamel, I am sorry you did not hear the discussion, but I must inform you that there is a motion before the chair that the report be received and adopted and the committee continued, so that you will have to speak to the resolution.

MR. SEELY: Before that motion is put, I should like to ask who is paying the expenses of the committee?

MR. AYER: It is under the supervision of the executive committee of the association. They levy and control it, as has been customary with all similar work. I will state for Mr. Seely's benefit that there is no opportunity here for any expense that is material.

THE PRESIDENT: Does any other member wish to speak to the resolution? You have heard the resolution. Is it your pleasure that the motion be declared carried? All in favor say aye. Contrary.

I declare the motion carried.

THE PRESIDENT: Is there any other business to come before the regular convention before we adjourn to meet in executive session?

MR. SEELY: I move that the secretary be instructed to prepare a set of resolutions for the retiring president, as is customary in our association.

MR. WILMERDING: I second the motion.

(Mr. Ayer in the chair.)

The chairman put the question, and it was determined in the affirmative.

(President Nicholls in the chair.)

THE PRESIDENT: Is there any other business to come before the regular convention?

MR. INSULL: I am under the impression that the record does not show a vote of thanks to Mr. White for his paper yesterday. It may be that I was not

paying particular attention when it passed, but that is my impression.

THE PRESIDENT: I am under the impression, Mr. Insull, that it was passed. At all events, I think the point is well taken. If there was such an oversight, I think it should be corrected, and that there should be a vote of thanks inscribed on the minutes, to appear in its regular order in the proceedings of this convention.

MR. INSULL: I meant to raise the point yesterday afternoon, but forgot it. I do not think the resolution was passed.

THE PRESIDENT: Your wish is, sir, to have it inscribed on the minutes in its regular order?

MR. INSULL: Yes; I make a motion to that effect.

THE PRESIDENT: I do not think we need take a vote on it at all. It is simply a question of precedence.

(The vote of thanks to Mr. White was passed at the third session of the convention, having been moved by Mr. Ferguson and seconded by Mr. Seely.)

# COMMITTEE ON AMENDMENTS TO FREIGHT CLASSIFICATION OF ELECTRICAL APPARATUS AND GOODS

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MR. AYER: Mr. President, may I call attention to the matter of freight classification? The freight classification on electrical merchandise is out of all reason; that is to say, there is no discrimination. You can ship a dynamo frame with no wire on it, just a simple piece of casting, and you have to pay freight on it as electrical merchandise at double first-class classification. Where plants were installed it was very common for the manufacturer to sell the goods installed. I still think we pay the freight; we are the buyers; and we certainly are all interested—all central station men are, and other purchasers, as well as the manufacturers, in having equitable rates made—in having electrical goods properly classified. They put all classes now under the highest class. I would suggest the appointment of a committee to take this matter up with the chairman of the Traffic Association, with a view of revising the freight rates. It is a pertinent thing, I think, for this association to do.

THE PRESIDENT: Would you appoint a special committee, or leave it to the executive committee?

MR. AYER: A special committee, I think. The executive committee wouldn't attend to it, from my past experience.

THE PRESIDENT: I would suggest that Mr. Ayer add this to his resolution: *A special committee, to be appointed by the incoming president*, as the work will

be attended to during his regime; if it is so understood I will put the motion in that form.

MR. AYER: I should be very glad to amend the motion in that way.

MR. SEELY: I second the motion.

THE PRESIDENT: It is moved by Mr. Ayer, seconded by Mr. Seely, that a special committee be appointed by the incoming president to take up the question of amendments to the freight classification on electrical apparatus and goods. Is it your pleasure that the motion carry?

Carried.

THE PRESIDENT: Before we adjourn definitely, there is one matter that I want to bring before members of the association. I want to refer to the great loss that the association has met with during the past year in the death of our esteemed active members, Mr. Harrison J. Smith, of New York, and Mr. J. M. Orford, of Boston. They were always with us; they were, I think, in attendance at every convention. We knew them as friends; we admired them as business men and as men foremost in their respective callings. Although it is not necessary to adopt any formal resolutions, I thought it not fitting that this meeting should close without some reference by the chair to the loss that the association has sustained.

If there is no other business, a motion to adjourn will be in order, and the active members will remain for executive session.

On motion of Mr. Seely, duly seconded, the convention then adjourned to executive session.

# EXECUTIVE SESSION

THE PRESIDENT: The first order of business is the report of the secretary and treasurer. Mr. Seely, as chairman of the finance committee, practically the treasurer, made that report during the opening session. Unless he has anything further to add, we will consider that report as already received and adopted.

MR. SEELY: I have no further report to make, Mr. President.

THE PRESIDENT: The next is the report of the executive committee. It will not be necessary in this case, I think, to make any report, because the interim reports that you have received from time to time have explained as fully as possible the work that has been undertaken by the executive committee during the past year.

The next order is the election of officers. I would ask the nominating committee appointed this morning, consisting of Mr. Huntley, Mr. Fairbanks and Mr. Seely, if they are ready to make their report.

MR. HUNTLEY: Mr. President, your committee have met, and we beg to submit the following nominations:

For president, Samuel Insull.

First vice-president, A. M. Young.

Second vice-president, George R. Stetson.

For members of executive committee: W. Worth Bean, St. Joseph, Michigan; W. McLea Walbank, Montreal, Canada; F. A. Gilbert, Boston, Massachusetts; E. H. Stevens, Elizabeth, New Jersey.

Mr. Huntley: I move the adoption of the report Mr. President.

Mr. Ayer: I second the motion.

The President: You have heard the motion by the chairman of the committee, seconded by Mr. Ayer, for the adoption of the report of the committee on nominations. Is it your pleasure that the nominations be received and adopted and the gentlemen recommended for election be hereby declared elected? All in favor say aye; contrary, if any.

Carried.

The President: I declare Mr. Samuel Insull elected president; Mr. A. M. Young, first vice-president; Mr. George R. Stetson, second vice-president; Mr. W. Worth Bean, Mr. W. McLea Walbank, Mr. F. A. Gilbert and Mr. E. H. Stevens, as members of the executive committee; all elected unanimously.

There is one point not referred to by the chairman of the committee. Three of the members of the executive committee are to hold office for the full term; one member is to be elected for the unexpired term of Mr. Young, Mr. Young having been elevated to the position of first vice-president. Are the committee prepared to amend the report, or to state how they intended the matter to be arranged? I presume that the last one mentioned is to fill Mr. Young's unexpired term.

Mr. Huntley: That matter was not considered; in fact, it was an oversight on the part of the committee, and inasmuch as at other times the secretary has cast the ballot for those who were named for the respective years, I would suggest the same course in this instance.

Mr. Seely: It has been customary, Mr. President,

that the last named should serve for the unexpired term.

THE PRESIDENT: That is the reason I suggested this; I know that has been the rule. Was that your intention as a member of the committee?

MR. SEELY: That was my intention, Mr. President.

THE PRESIDENT: Mr. Fairbanks, was that your intention?

MR. FAIRBANKS: Yes, sir.

THE PRESIDENT: Can we then consider that that was the intention of the committee, and so declare? Is it your pleasure that I so declare it? All in favor, say aye; contrary, if any.

Carried.

THE PRESIDENT: I declare Mr. Stevens a member of the executive committee to serve for the remainder of Mr. A. M. Young's unexpired term.

THE PRESIDENT: Mr. Insull, I have very much pleasure, sir, in inviting you to a seat upon the platform. I am sure the members would like to hear from you.

MR. INSULL: Mr. President and gentlemen, I appreciate very highly the honor you have conferred upon me in electing me to occupy the important position of President of the National Electric Light Association for the ensuing year. I appreciate it the more because I am personally acquainted with so few of you. All I can say is that I will do my very best to serve the interests of the association, and I do not think that those interests can be better served than by continuing the policy of the out-going administration under the able presidency of Mr. Nicholls. I must say that I feel some hesitation about taking up the duties that will fall upon me in having to follow

a man who, from long acquaintance, I know has great ability and is very aggressive in trying to accomplish what he has set himself to do.

I do not think that you want a long speech from me at this time, but I wish you to understand that my appreciation is none the less because my remarks are short.

THE PRESIDENT: Mr. Young, the chair would like to introduce our first vice-president-elect in his new capacity.

MR. YOUNG: Mr. President, gentlemen, I can hardly find words to express the appreciation I feel for the honor conferred upon me, and I shall endeavor to aid our president in every way I can to increase the benefits of this association to every member.

THE PRESIDENT: Mr. Stetson, it is your turn.

MR. STETSON: Mr. President and gentlemen, in passing the table to-day at which were seated the committee chosen to nominate your officers, I was called to one side and the chairman informed me that I had been placed in nomination for this position. I told him it reminded me very much of the story of the man in Colorado who was tried for murder, and after the jury had been out for ten minutes, a man stuck his head in at the window, and said they didn't want to hurry the jury, but they would be pleased to have the room to lay out the corpse in. It seems to me that my election tc this position is an honor that I had no right to expect. While I am very much interested, and while I suppose there is not a man in this country that more admires the intellectually ability of the gentlemen that are represented in this cause, at the same time it seems to me that this must be considered as an honor conferred upon me such as I can expect in the natural course

of things to receive but few more of, and I certainly appreciate it very fully.

THE PRESIDENT: Gentlemen, is there any other business to come before the meeting in executive session?

Before a motion to adjourn is made, in retiring publicly from the position of president of the association, I wish to extend my thanks to the officers of the association for the way in which they have aided me in my efforts during the past year. I also wish to thank most sincerely and heartily the members that have been present at the convention for their regular attendance at the meetings, for the orderly way in which the meetings have been conducted, and for the hearty manner in which they have shown their appreciation of whatever efforts I have been able to make as your presiding officer. I also wish to thank the gentlemen who, at the sacrifice of a great deal of time (because I know what time it takes), have prepared for us the several interesting papers that have been submitted at this convention. In fact, they have been so interesting that I regret that the convention is not to remain at least one day longer in session, so that each of the papers could receive the discussion that it deserves and which would be edifying to everyone present. In retiring from the position to which you elected me, I wish to thank you all again very heartily.

A motion to adjourn will be in order.

On motion the convention then adjourned.

# APPENDIX

# THE DAYLIGHT WORK OF CENTRAL STATIONS.

BY T. COMMERFORD MARTIN.

The development of the central station industry has been, in some respects, a disappointment. We have now had nearly twenty years of central station work in this country, and have witnessed an enormous growth in that period within the field of work covered by this organization, but it is apparently as true to-day as when the association was formed, that the companies restrict themselves injuriously in their natural and logical advance by remaining mere lighting corporations. What would happen to us all if some new lighting medium came into vogue that deprived us of our illuminating business entirely? If we had to fall back on daylight work, might we not be better off?

That question suggests an extreme view of a rather impossible situation, the fact being that electricity, as an illuminant, gains steadily in public estimation, and has, at this moment, no new rival within speaking distance. But there is vital importance in the opinion of a local company as to whether it exists only to furnish light, or, on the other hand, to supply current for a variety of uses, new and old. My own opinion, modestly expressed, is that the intrinsic value of a company rises just in proportion as it gets off the lighting basis and builds itself up on that of current; just in proportion as it ceases to limit its activities by a moonlight schedule, and, like the British drum-beat, chases the sun with

an insatiable, twenty-four desire for more territory and more trade.

A brief retrospect will not be out of place, if followed by a study of the present situation. It is as well not to go back further than 1886, for, although arc lighting is a full decade older than that, the industry ten years ago took its great leap forward. A careful investigation shows that, in 1886, there were about 410 central stations in this country. Of these, only 300 furnish available statistics, and it would appear that 226 of the companies were then only doing a night arc lighting business. It is safe to assume that all the companies which did not report were in the same category as the 226; so that, out of the 410 local companies, some 325 were doing business only between dusk and daylight, and were standing idle all the rest of the time. In other words, taking the year through, they were idle nearly two-thirds of the day, if the average running be taken at 3,000 hours a year.

To what degree have these conditions been improved in the ten years? This is an extremely difficult question to answer, but a few tentative figures may be acceptable as a basis for study and discussion. At the close of 1896 there were about 2,400 central stations in operation in this country, so that in ten years the number had increased sixfold, a gain that is simply stupendous. Of these 2,400, however, 975 had, from the figures obtainable, no day circuits, and 220 others had only arc apparatus, so that 1,195 local companies, by their own admission, were limited to night work. The case is not, however, so encouraging as might be implied from these figures. Of the remaining 1,200 companies, only 327 report day circuits, and if it is safe to assume that half of the 900 companies and plants not

giving these details were without day circuits, it would appear that, out of 2,400 local plants, at least 1,500 are limited to the night hours for their earning capacity. It must be noted, however, that nearly all the 900 companies not specifying day circuits are operating incandescent circuits, very largely with the alternating current, so that the means for day operation are generally there under more or less favorable conditions.

It is obvious at once that an immense amount of capital and machinery is standing idle that might otherwise be productive of profit and dividends. Of the 1,200 companies confessing that they have no day circuits, only some 780 give their figures of capital and generating capacity in steam or water. It would appear that these plants, with a moderate capitalization of $46,908,000, and with an engine and water-wheel capacity of 164,000 horse-power, are standing idle two-thirds of the day and often a great deal longer.

Such figures are given broadly, and may be a little inaccurate in precise detail, but it is the mere fact that is so striking. It is obvious that these figures apply to the great bulk of small stations. And yet some of them are certainly not small. At least sixty-five or seventy of them have each a capacity of 500 horse-power and upwards, and several of them are legitimately capitalized at above a million dollars each. A company of such size ten years ago was rare and exceptional, and would have been difficult to start, except on the general hypothesis that its business would include something beyond simple street illumination, with a little house lighting thrown in. It may be doubted whether capital of any magnitude could be enlisted to-day for a company that had no ideas beyond ordinary lighting work.

Without presenting this state of affairs as a cause

for alarm, or intending to imply that a business is necessarily on a bad basis because limited to a few hours, it is not improper to inquire whether there is no chance for improvement. It can not be said that local lighting companies have become notorious, like some gas companies, for paying large dividends; so that a slight amelioration of financial condition might not be objected to. Even trolley roads, running every hour of the day, find it difficult, sometimes, to make ends meet, but they have the satisfaction of a continuous use of their plant and of knowing that they get all the business that offers. If there is any sufficient reason why a local lighting company should operate its generating machinery fewer hours than a trolley road, it has not made itself specially manifest, except in one direction, which will be briefly referred to in a later paragraph. I believe every gas company is on a twenty-four-hour basis of supply.

If the stationary motor work, whose claims I ventured to urge on this association eleven years ago, had been left to the local lighting companies, I fear it would not have made much headway. The 327 and other companies with day circuits do an enormous amount of power work, but a careful analysis of somewhat incomplete data would lead one to believe that the isolated plants are the real backbone of the electric power industry to-day. Why this should be so, it is difficult to explain, except on the hypothesis that station current, when obtainable, often costs too much, and is generally not obtainable. It will, I trust, be understood that this paper is not offered in any wise as a criticism of central station management, but simply a presentation of the puzzling facts that confront students of the situation. No one can know the inwardness of the problem so well as the central

station manager himself, and no one can be more deeply interested than he in dealing with it wisely and well.

It might be said that, in a general survey, four new factors have presented themselves in the last ten years for the consideration and approval of the central station manager. These are motors, alternating-current supply, storage batteries and electric heating. The alternating current is, for most stations, still restricted to night-work, and will be, probably, until more single-phase motors of successful character are on the market. This form of current has given such a tremendous stimulus to lighting that it deserves a wider range of usefulness, so that, in time, alternating-current stations may compete with direct-current stations as earners of dividend.

Allusion has already been made incidentally to motor work. What is possible in this direction is best judged from what the large stations do. Of course, this is in some respects an erroneous guide, but in the same manner as great men are exemplars for those of less heroic bulk, so the large stations indicate the actual possibilities, even for a lower plane of execution. The following are figures of a large western central station, showing the horse-power of motors connected to the circuits, and the percentage that the power consumption bears to the total output. The data come down to March 31, 1897.

LOW TENSION.

| | |
|---|---|
| Power connected April 24, 1897 | 5,396 horse-power. |
| Power per cent. of the total output | 23.1 per cent. |

HIGH TENSION.

| | |
|---|---|
| Five hundred-volt power connected April 24, 1897 | 1,566 horse-power. |
| Power per cent. of high-tension output | 21.4 per cent. |

ALL SYSTEMS.

| | |
|---|---|
| Power connected April 24, 1897 | 6,962 horse-power. |
| Power per cent. of the total switchboard output | 22.8 per cent |

Another example is to be found nearer home, in the work of the New York Edison company. The motors to which that company supplied current from its distributing mains represented, on January 1, 1896, a total installation of 11,640 horse-power. On January 1, 1897, the motors connected were the equivalent of 15,930 horse-power, an increase of motors connected in a single year of 4,290 horse-power, or thirty-six per cent. This does not include an installation equivalent to 1,142 horse-power in motors, to which current is supplied from the New York Edison stations during minimum hours, or for emergency and break-down connections. It will be seen that this brings the total horse-power in motors connected to the company's mains up to 17,072 horse-power. The average size of these motors is from three and one-half to four horse-power. Of the total motors connected it is estimated that about 5,000 horse-power, equivalent, is installed in connection with direct electric elevators and grip hoists.

In order that the idea should not go abroad that the big companies are monopolizing the power business, but that it is open to all, I would mention that in Massachusetts, where there is only one large city, no fewer than eight companies out of fifty-eight are supplying power from their arc circuits; eighteen from incandescent circuits, and twenty-nine from independent power circuits; the total being about 14,000 horse-power of motors on the circuits. The asking rate for kilowatt hour averages about twenty cents, but runs down as low as ten cents.

Turning next to storage batteries, it is not my intention to agitate old discussions, but simply to give a few figures, which would go to show that the batteries may do more than perform the Alpine feat of

taking care of the peak of the load. There are at the present time in America—I blush to give the figures—only fifteen central stations using batteries, with a total capacity of 25,000 horse-power hours output. Four other stations are being equipped. I hope devoutly that some future chronicler will be able to report that 1,500 stations are equipped with batteries, and that by their reservoir capacity they have answered in the affirmative the question whether their life was worth living. What batteries can do is best exemplified by the Duane street station of the New York Edison company, one of the biggest stations in the world, with an engine and generator capacity of 20,000 horse-power. The load during minimum hours, I am told by Mr. J. W. Lieb, Jr., the general manager of the company, is such that it can be supplied in that period from the storage battery annex at the Bowling Green Building in the southern tip of the tongue of Manhattan Island; or from the storage battery plant at the Twelfth street station, either alone or in conjunction with current supplied from the Twenty-sixth street station over the feeder tie lines. The supply of stored current from the batteries in the annex stations during the minimum hours enables the big Duane street station to be shut down every night from 10.30 p. m. to 5 a. m.—nearly seven hours; and on Sunday the operation of the generating machinery at Duane street is limited to one watch. I do not hold a brief for storage batteries, but in view of such facts it is hardly possible to do other than press their claims on the attention of central station managers.

A word in conclusion as to electric heating. When I hazarded, eleven years ago, before this

body the expression of an opinion that motors ought to be pushed, it was regarded in many quarters as premature and visionary. From a conservative standpoint, it was so undoubtedly; but in everything success is not to be gauged by the point you are at. The real test is the way you are going; and if the tendency is right, all else that is desirable comes in due time. Now, in central station work, we can and must recognize but one tendency as the underlying and ultimate; namely, to increase the demand for current, and whatever does that is to be welcomed. To-day, electric heating, using that term in its generic sense to cover a variety of uses and purposes, stands just where electric power did ten years ago. It is a parvenu, hardly admitted or recognized in good electrical society, but a "pushing young particle" that there is no snubbing or subduing. Much more recently than ten years ago, I was involved in a hot daily newspaper controversy in New York, with the object of proving that electric power had the ghost of a show; and now the advocates of electric heating are similarly put on their mettle. The main argument they have to contend against is an elaborate formulation of caloric theories and laws, all going to demonstrate the terrific loss and cost of heat units when delivered electrically to the man who wants them.

It is said that, with current sold on the basis of twenty cents a kilowatt hour, no business can be done in heating, and that, even if the price be cut in two, the inducement to possible customers is not great. If this were true, the matter of price of current might forbid the operation of a single fan motor from central stations. Making a rough calculation of one cent per hour for the ordinary fan motor, that is ten

cents a day for ten hours steady running, or, say, $3 per month or $36 a year. Allowing twelve such motors to the horse-power, the local companies are selling current to thousands of willing customers in the summer time at the rate of $430 a year per horse-power, for a working day of only ten hours. Other quotations can be made showing the high price got readily for current in small quantities from purchasers who are perfectly satisfied with the bargain, and find it pays them also very handsomely in some element of comfort, pleasure, convenience or even economy..

A test taken three years ago, for twelve weeks, of current consumed in cooking a dinner of several dishes daily for a large number of persons, showed that for ninety-seven persons the current fell as low as 307 watt hours per person. This would make 29,779 watt hours, or, in round figures, thirty kilowatt hours. At ten cents per kilowatt hour, that means an expense of $3 per day, or, say, $90 per month. It will, of course, be objected that, in a great many isolated plants, the current made on the spot does not cost to exceed five cents per kilowatt hour, which would, in the building where the test was made, have brought the sum down to $45. I have tried to get some basis of comparison between this and an equal amount of work on a gas-stove or range, for an equal number of persons, but it is not easy to obtain. In one family I know, which consists of six persons, they have been cooking by gas for some five years. It costs, with gas at $1.25 per 1,000 cubic feet, on an average, $5 to $6 per month, or from sixteen to twenty cents per day, or about three and one-half cents per head per day, if all are at home to every one of the three daily meals, which is far

from being the case. If the same expense averaged for the ninety-seven persons for three meals daily, the outlay for gas in cooking would be between \$90 and \$100 per month, or about as much, if my figures are approximately right, as electricity would cost, if the current were supplied at five cents per kilowatt hour. This is certainly a very encouraging showing for electricity, but we must not forget that central stations do not exhibit much anxiety to sell their current at five cents per kilowatt hour, or even per horse-power hour, and this is one reason why isolated plants have multiplied so tremendously in our cities. I might add, as one point of interest, that, when the family I mention began to cook with gas, it bought a gas-range for \$25 and paid \$2 or \$3 more to get it set. The range has worn out, and the family is now hiring a good one from the local gas company for \$3 a year.

From these crude remarks of mine, it will be seen how sadly tentative and experimental the art of electric cooking is for most of us; but is it not the duty of the local lighting companies to go into this matter and see how far they can foster the new art, by introducing the apparatus and furnishing current for it cheaply? Even if the price falls short of \$430 per horse-power per year, for ten hours a day only, they should not feel discouraged.

I have spoken of cooking, but this is but one of many fields of usefulness for electric current heating supply. Our esteemed ex-president, Mr. J. I. Ayer, who has placed at my disposal much interesting data that I can not produce here, for lack of time, gives me also a variety of information as to work that has lately fallen within his sphere of practical attention as representative of a large electric heating company.

Their work includes a wide extent of shoemaking machinery, heated silk-finishing rolls, leather-working machinery, 387 curling-iron sets in the dressing rooms of the combined Waldorf and Astoria hotels, in New York city, seventy-two sets in the Parker House, Boston, and apparatus in the Plankinton and Pfister hotels, Milwaukee, as well as on the American line steamers across the Atlantic. It would not be fair to omit the 14,000 car heaters installed, of one make alone, in the past year and a half. A blank-book manufacturer has had in use since 1894 from thirty-five to forty electric glue pots, and Duryea & Co., the starch-makers, are also users of electric heat apparatus. In Knabe & Co.'s piano factory, at Baltimore, twenty electric heaters have recently been placed; and there is a long list of clothing houses throughout the country that use electric irons. The same is true of vulcanizers for bicycle tire agencies and factories, while irons in large numbers have been supplied to State asylums in Indiana, Michigan, Wisconsin, Illinois, New York, Massachusetts, Maine and Maryland. It is simply impossible that all this apparatus should have been put in, unless it was economically or practically worth while; and this being so, is not the electric heat field one in which the local companies can now begin to work with advantage? Surely, here lies opportunity of the largest kind, to help the introduction of apparatus that must serve as a large customer for current at all seasons of the year.

The subjects I have brought up are perhaps inexhaustible, but, in spite of the labor and tax on scant leisure involved in collating some of this data, I shall be repaid if in the smallest degree a stimulus is given to central station work and prosperity.

I feel sure that whatever remarks I have made will be accepted in the spirit that prompts them—one of heartiest good wishes for the welfare of the typical comprehensive industry of the age—that of the electric central station.

## PRESIDENT'S INTERIM REPORT

DEAR SIR: When elected president of your association, I fully realized that much useful work might be accomplished during the interval between conventions, and have earnestly endeavored since our last annual meeting to initiate and, with the assistance of our secretary, to conclude certain matters which I am hopeful will be approved of by our members, and upon which I now have the honor to report as follows:

### RELATIONS BETWEEN MANUFACTURING AND CENTRAL STATION COMPANIES

At our last convention the Committee on Relations between Manufacturing and Central Station Companies was discharged, and the executive committee authorized to take such action as might, from time to time, be found necessary, in an endeavor to protect its active members from having their investments in central station companies destroyed, or seriously impaired, as a result of ruinous competition, directed or fostered by the manufacturing companies. At an early period of my administration, such a case arose, in a western town, as justified prompt and energetic action on the part of your association. After consultation with the members of the executive committee, I placed the views of our association, as to this particular case, and as to unwise and unwarranted competition in general, before the executive officers of the following manufacturing companies:

Ball Electric Light Company,

Brush Electric Company,
Fort Wayne Electric Corporation,
General Electric Company,
Royal Electric Company,
Siemens & Halske Electric Company,
Stanley Electric Manufacturing Company,
Western Electric Company,
Westinghouse Electric and Manufacturing Company.

The details of our negotiations, by correspondence and in some cases by personal interview, are too voluminous to here set forth, but it is with much satisfaction that I am able to report that each of these companies, with the exception of the Ball Electric Light Company, has given favorable consideration to the representations made on behalf of your association, and I have received, in writing, such satisfactory assurances, regarding not only the particular case in question, but also as to their future general policy, that I am hopeful of good results. Should, however, any active member have reasonable cause for complaint, he should forward full corroborative details to our secretary, and the association will take prompt and energetic measures, if the circumstances warrant such action.

MUNICIPAL LIGHTING STATISTICS

Being aware that no recent and reliable statistics of the cost of arc lighting in the cities and towns were available for use by members of the association, I some time since instituted correspondence with the municipal authorities of each city and town in the United States, with the object of securing from official sources and by official authority reliable information from each place as to (1) the number of arc lamps, (2) their candle power, (3) the hours of burning, (4) the

cost per lamp per night. Accompanying this report you will receive, in pamphlet form, a preliminary bulletin, containing such information from over four hundred cities and towns, which list covers a very large majority of the principal installations. A supplementary list, containing similar information in regard to places now omitted, is in process of compilation, and will be issued to members at an early date. It frequently happens that when a contract is to be renewed, local papers publish very misleading figures concerning prices paid for arc lights in other municipalities, and as these statistics are of the months of June and July, 1896, they are reliable and up to date.

### LAWS AFFECTING ELECTRICAL COMPANIES

We have been in correspondence with the secretaries of state for each of the states in the Union, with a view to making arrangements to have regularly forwarded to the association copies of all bills introduced in any state that may deal with the rights of electrical companies. I am much pleased to be able to report that a large majority of the states have acceded to our request, and several have already forwarded copies of all bills passed during the past session of their legislatures, while others have promised to forward any that may be introduced during future sessions. These will all be filed in the secretary's office for the sole use and advantage of the members of the association.

### REVISION OF CONSTITUTION

As the only printed copies of the Constitution and By-Laws of the association did not contain recent additions and amendments, revised copies have been published, and may be obtained from the secretary.

## REPORT OF PROCEEDINGS OF NINETEENTH CONVENTION

The report of the recent convention held in this city is now in the printer's hands, and will be delivered to members not later than September 1st, next. There has been some unavoidable delay, caused by speakers at the convention failing to revise the stenographic copy of their remarks, but, so far as my memory serves, it will be issued much in advance of previous reports.

## IMPROVED OFFICE FACILITIES

The office of the association being too small to be of service to our members visiting New York, the chairman of the finance committee made arrangements to rent the adjoining office, with the special object of providing a room for the use of our out-of-town members. The office is centrally located in the downtown business district. Members can use this room for meetings, appointments, etc., and their letters and telegrams can be addressed here. As the records of the association are increasing in number, two new bookcases have been provided, and already contain many books of reference.

In conclusion, I wish to bear testimony to the zeal of our secretary, without whose enthusiastic co-operation it would have been impossible to have accomplished so much in so short a time. I also have to request that members will aid me, by suggesting any action that may promote the welfare and add to the usefulness of the association.

Yours faithfully,
FREDERIC NICHOLLS,
President.

NEW YORK, August 1, 1896.

## PRESIDENT'S INTERIM REPORT, NO. 2

DEAR SIR: I have to advise you that, since issuing my first Interim Report in August last, the officers and executive committee of the association have been actively engaged in endeavoring to promote the interests of the association and its members. There have been many services performed for individual members, which, being more or less of a private nature, are not set forth herein, this report dealing more directly with the public policy of the association and such other matters as may be of value to the electric lighting interests in general.

### INCREASED MEMBERSHIP

I am pleased to report that a number of new members have been added to the roll of the association within the past few weeks, and that the prospects are that, before our next convention, we shall have a larger active membership than at any time previous; and our secretary, who has just returned from a visit to a number of central stations, reports that an active interest is being taken in the work of the association.

### MUNICIPAL LIGHTING STATISTICS

In August last we issued to members, for confidential use, a preliminary report of the cost of arc lighting in the cities and towns of the United States,

and promised a supplementary report at an early date. This supplementary report has been incorporated with the preliminary one, and the bulletin containing these statistics has been compiled with an end to handy reference, and is most complete. A copy is herewith inclosed.

REPORT OF COMMITTEE ON DATA

The most important standing committee of the association has been the Committee on Data, and it has been a matter of regret that the self-sacrificing efforts of its able chairman, Mr. H. M. Swetland, have not heretofore met with the support to which they were entitled. The information for the guidance of the committee was sought to be obtained in the past by correspondence and the filling out of blank forms, but always with discouraging results.

This year, with the approval of the executive committee, a different course has been adopted. Mr. Swetland and myself have had several conferences regarding the matter and scope of the report for our next convention, and a practical engineer of high standing has been retained to personally visit a number of central stations in the East and West, and gather from first hands the information we have decided upon as being necessary. I have this week carefully reviewed such portions of the report as have been completed, and can promise our members that it will, in my opinion, when completed, be the most valuable publication yet issued by the association. It will be printed in book form, and will, I hope, be ready for distribution on or about March 1st, next, so that members may have ample time to prepare for its discussion at the convention.

CONSOLIDATION OF LIGHTING AND RAILWAY INTERESTS

While admitting that there is plenty of room for widely divergent views as to the benefit, or otherwise, to those interested in a consolidation of the National Electric Light Association and the American Street Railway Association, I considered that the present was an opportune time for the discussion of the subject, and wrote Mr. H. M. Littell, president of the latter association, suggesting a conference. A letter, of which the following is a copy, has been received from the secretary:

OFFICE OF

THE AMERICAN STREET RAILWAY ASSOCIATION,

2020 STATE STREET,

"CHICAGO, September 21st, 1896.

"FREDERIC NICHOLLS, ESQ.,
"President National Electric Light Association,
"Toronto, Ontario.

"DEAR SIR: The following is an extract from the minutes of a special meeting of the executive committee of the American Street Railway Association, held in New York City, September 9th and 10th, 1896:

"'A letter from Mr. Frederic Nicholls, of Toronto, Ont., President of the National Electric Light Association, relating to the matter of the consolidation of the two associations, was read, and the secretary was instructed to notify Mr. Nicholls that the executive committee would be willing to have Mr. Nicholls appoint three representatives of the National Electric Light Association, engaged exclusively in the lighting business, to confer with three representatives of the

American Street Railway Association, engaged exclusively in the street railway business, and that those gentlemen consider the subject fully.'

"Yours truly,

(Signed) "T. C. PENNINGTON,

"Secretary and Treasurer."

I have appointed the following active members of our association: Mr. W. S. Barstow, Brooklyn, New York; Mr. Henry Clay, Philadelphia, Pennsylvania; Mr. Chas. E. Scott, Bristol, Pennsylvania, to confer with the gentlemen to be appointed by the American Street Railway Association.

LEGAL OPINION REGARDING THE RIGHTS OF LIGHTING COMPANIES TO USE OF STREETS FOR OVERHEAD WIRES

The following request for information was recently published in a New York electrical journal:

"We are having trouble with house movers cutting our wires, claiming that they have a right to the highway. Our attorney here does not find any law bearing directly on this trouble, and we wish to make them stop bothering us if the law is with us. Please cite us to where we will find cases of this kind decided, and any other information relating to same will be thankfully received.

"Yours respectfully,

"MCPHERSON WATER AND ELECTRIC COMPANY,

"J. E. WRIGHT, Manager.

"MCPHERSON, Kansas, September 15th, 1896."

The correspondent was referred by the editor to the secretary of the National Electric Light Associa-

tion as being the most likely source from which to procure the information desired. Although this is one of those questions usually considered private, and the information sent direct to the inquiring member, I have thought that an opinion on the rights of central station companies to the use of the streets for the purpose of stringing wires would be of interest to our members generally, and therefore submit herewith an opinion from Mr. Eugene H. Lewis, of the legal firm of Messrs. Eaton and Lewis, of this city:

OPINION

S. B. EATON. LAW OFFICES OF EUGENE H. LEWIS.

EATON & LEWIS,

44 BROAD STREET (EDISON BUILDING),

"NEW YORK, October 2d, 1896.

"FREDERIC NICHOLLS, ESQ.,

"Toronto, Canada.

"DEAR SIR: You have requested my opinion as to the rights of owners of electric-light wires strung along the streets of a city as related to the rights of the owners of buildings to move them along the highway and to cut all wires interfering with their progress.

"It is difficult to give a satisfactory answer to a question of this character that would be applicable to both cases, as different states have different rules of public policy, and in different states the statutes, municipal charters and grants differ so widely as to render each case independent of others and determinable only upon the facts specially pertaining to it.

"My opinion in general is that the moving of a building along a highway is not one of the rights enjoyable by the general public in a public highway for the purpose of travel, and that if a person moves a building along or across a highway, he must do it

with due regard to the rights of property enjoyed by those who are then using the highway for puposes of transmitting electricity for power or illumination. You will hardly expect me to give my reasons in detail for this view, and I will not do more within the limits of this letter than to refer you to a few cases which have come under my observation bearing upon this subject.

"*New York & New Jersey Telephone Company vs. Dexheimer.*

(14, N. J. Law Journal, 295.)

"In that case telephone wires were stretched across the highway in pursuance of the act under which the company was incorporated and with the consent of the municipal authorities. There was a proviso in the charter that the wires should be so located as to in no way interfere with the safety or convenience of persons traveling on or over the roads or highways. There was a statute declaring that the use of a public street 'in any of the incorporated cities or towns of this State, shall be subject to such regulations and restrictions as may be imposed by the corporate authorities of said cities or towns.' The city of Orange had adopted an ordinance declaring that 'all telegraphic and telephone wires shall be placed so as to hang not less than twenty feet above the street crossing.' The defendant had a special license to move a house along a street, and in moving it he cut all the overhanging wires, and in an action by the telephone company it was insisted on the part of the plaintiff that thirty of these wires were more than twenty feet above the street. Judge Depue, of the New Jersey Supreme Court, charged the jury that the use of a public highway in moving a building was not within the right enjoyable by the public in a public highway for the purpose of travel, and that the defendant's act was not justified on the ground that he was obstructed in the use of the highway for public travel. He held, however, that since the defendant

had a special license to move the house, the defendant was justified in cutting such wires as were maintained in violation of the city ordinance less than twenty feet above the surface, and he left it to the jury to decide whether any of the wires that were cut were more than twenty feet above the roadway, and to assess damages for the cutting of these, and these alone.

"The case of *Williams vs. Citizens' Street Railway Company* (8, Street Railway Journal, 102) arose in the State of Indiana, and was decided by the Indiana Supreme Court in December, 1891.

"In that case it appears that a church congregation, with the tacit permission of the city council, sought to move its edifice across a street occupied by a line of street railway, operated by electricity, with the overhead wire system. The building being too high to pass under the wires, the contractor employed by the congregation threatened to cut the wires, relying upon the tacit permission of the city and upon the claim that the company had forfeited its right in the streets by changing its motive power without specific authority. In a suit by the company, to enjoin the threatened destruction of its property, the point was made by the defendants that the court had no jurisdiction to control the city council in the exercise of its authority over the streets. The court, very promptly and properly, decided that the authority to determine legal controversies concerning personal or property rights had not been vested in the common councils of the cities of that State; that the failure or refusal of the common council to take steps to prevent the injury or destruction of the railway property did not preclude the company from seeking redress in court; that no individual could insist that the corporate existence of the company had terminated, or that he could, at pleasure, confiscate or destroy its property in order to move a house across its tracks; and that, although citizens had the right to the ordinary use of the streets, they could not interrupt traffic or discommode the public by tearing down street car lines in order to remove buildings along the streets.

"In your own city of Toronto, there arose the case of *Toronto Street Railway vs. Dollery* (112, Ont. App., 679), in which it was held that a person cannot lawfully blockade the tracks of a railway company by moving a building.

"It is true that as far back as 1852, in the case of *Telegraph Company vs. Wilt* (11, American Law Journal, 374), it was held that legislative authority and municipal license to set up a telegraph line in the street, were no defense in an action for injury to a house being moved along the street and caught by the wires. But that case does not seem to have been well considered, nor has it been generally followed by the courts, and it is expressly disapproved by Scott & Jarnagin in their works on telegraphs, section 53.

"I have not had time since receiving your request to search the decisions of the past three years relating to this subject, but, in my opinion, the foregoing cases in New Jersey and Indiana are much more likely to be followed than the case last referred to.

"I hope that the views expressed in these few lines will avail you for your purpose.

"Yours truly,

(Signed) "EUGENE H. LEWIS."

### STANDARDIZATION OF INCANDESCENT LAMP SOCKET AND BASE

The question of a standard incandescent lamp socket and lamp base has frequently been discussed in an informal way at meetings of the association, but no effort made to bring together those most directly interested.

Believing that much might be accomplished by holding a meeting under neutral auspices, I wrote to the manufacturers of sockets and lamps, inquiring if they would be willing to attend a meeting to discuss

ways and means of endeavoring to solve this difficult problem, if such were called by the association. The replies received were unanimous in their expressed desire to be present at a meeting to be called by the association for such a purpose, and I therefore, on the 24th ultimo, issued the following notice of meeting:

"NEW YORK, September 24th.

"DEAR SIR: I beg to advise you that a meeting of manufacturers and central station men, to discuss the possibility of standardizing the incandescent lamp base and socket, has been called for Friday, October 9th, commencing at 10.30 a. m. The meeting will be held in the rooms of the American Institute of Electrical Engineers, which are situated on the tenth floor of the Havemeyer Building, 26 Cortlandt street, corner Church, this city.

"I may say that every manufacturer previously advised of the intention to hold a meeting has notified us of their desire to be represented.

"FREDERIC NICHOLLS,
"President."

"NEW YORK, October 5th, 1896.

"While I am doubtful of any direct result towards the desired end from this first meeting, I am hopeful that we can enter the thin end of the wedge at least, and by sustained and persistent effort accomplish what we have in view.

"In conclusion, I have to request that members will promptly communicate with our secretary on any subject that properly pertains to the business of the association, and regarding which they may desire information or action.

"Yours faithfully,
"FREDERIC NICHOLLS,
"President."

# PRESIDENT'S INTERIM REPORT NO. 3

Dear Sir: At the close of my last interim report I referred to a meeting of lamp and socket manufacturers that I had called, to be held under the auspices of this association, to discuss the question of standardizing the incandescent lamp socket and lamp base, and stated:

"While I am doubtful of any direct result towards the desired end from this first meeting, I am hopeful that we can enter the thin end of the wedge, at least, and by sustained and persistent effort accomplish what we have in view."

I now have to advise you that a most successful and well-attended meeting was held, accounts of which appeared in the electrical journals at the time, and that at the present good progress is being made, although some unexpected difficulties have arisen to delay a definite settlement. Late in December the National Board of Fire Underwriters, at a meeting held in New York City, amended the rule relating to sockets to read as follows:

"No portion of a lamp socket or lamp base, exposed to contact with outside objects, must be allowed to come into electrical contact with either of the conductors."

This amendment to the rules of the Fire Underwriters makes it necessary that any standard adopted should fulfill these requirements, and I propose calling another meeting at an early date, at which the committee appointed at the last meeting will report progress.

## REPORT OF COMMITTEE ON DATA

The report of this committee has been completed, and, after having reviewed same, I have no hesitation in saying that it will commend itself to the members of the association as being the most satisfactory report yet issued by this committee. It is now in the printer's hands, and will be ready for distribution some time prior to our next convention, so that members may come prepared to discuss the subject matter of the report, and suggest such other features as may appear to them advisable to have incorporated in future reports of this committee.

## REPORT OF THE COMMITTEE ON INCANDESCENT LAMP STANDARDS

Dr. Louis Bell, chairman of this committee, writes me as follows: Answering yours of January 6th, I am happy to report that your committee has made substantial progress. The matter was taken up with the Units and Standards Committee of the American Institute of Electrical Engineers, as originally planned, and, after much consideration, a final joint meeting was held in New York on December 16th last. At the next meeting of the American Institute of Electrical Engineers' Council, this committee on units and standards will lay down its report conjointly with your committee and we can then proceed to the practical part of the programme. The fundamental question taken up by the National Electric Light Association and the American Institute of Electrical Engineers' committees was the establishment of a standard method and apparatus for the measurement of candle power. This has been satisfactorily settled, and it now remains to arrange for the production of secondary standards

(*i. e.*, standard incandescent lamps to be used for purposes of comparison), and to draw up specifications for a uniform rating of lamps and its ready verification. It is the opinion of your committee that this reduction to practice of the scientific questions involved would be best accomplished by a conference of your committee with official representatives of the Institute and the lamp manufacturers, so that the final conclusions would carry the joint agreement and assent of these organizations, and an informal conference will soon be held.

PLANS FOR ESTABLISHING A LAMP-TESTING BUREAU

Most of our members are aware that your association has been endeavoring to promote the standardization of sockets and lamp bases, and the letter of Dr. Louis Bell, published above, shows that your committee has given prompt attention to the important question of standardizing the candle power of incandescent lamps, and, in this connection, I append hereto a plan for the establishment of a lamp-testing bureau, which has been forwarded to me by a member of our association. I shall be glad if every member will carefully consider these suggestions, and write me as promptly as possible in regard thereto, setting forth his opinion of the merits and demerits of the plan, which follows:

*Plans for establishing a lamp-testing bureau, and suggestions as to plans which, if agreed upon by lamp manufacturers and central stations, would make the bureau of great value both to the manufacturer and consumer.*

The proposed bureau to be in charge of an expert

employed by the National Electric Light Association, and methods of testing to be approved by a majority of experts of lamp manufacturers, who agree to abide by decisions of the bureau as to quality of product and fulfillment of guarantees.

Any lamp company, whose lamps are being tested at the bureau, will be allowed at any time to investigate the methods used and the accuracy of standards, but to have no access to records of the bureau, except as regards tests which have been, or are being, made on their own product.

The expense of maintaining the testing bureau will be met by the income of the bureau, as hereinafter provided, by certain definite charges for tests made, and could also probably be partially met by subscription or definite dues from central stations or other consumers, who would signify their intention of availing themselves during any year of the services of the bureau.

Lamp companies would be at liberty to guarantee their product at as high a standard of quality as they see fit, and the province of the bureau would be to determine whether such guarantees have or have not been fulfilled. Tests will be made by the bureau on guaranteed lamps furnished by any manufacturer, on application by the customer, the following conditions having been complied with:

1. Before test is made, the customer ordering the test should deposit with the bureau a sum equal to the estimated cost of such test at the following rates:

Initial tests or readings of lamps will be made at .... cents per lamp. Tests will be made to determine the value of a lamp burned at its marked voltage at .... cents per thousand watt hours.

Conditions under which tests will be made are as follows:

1. Not less than twenty lamps will be tested to determine the value of any given lot of lamps.

2. Where the value of any lot of lamps is to be determined, not less than two per cent of the entire number whose value is to be determined are to be furnished the bureau for test in their individual unbroken packages (this would only necessitate the placing of a seal or label on the wrapper of each lamp in such a manner that it must be broken to unwrap the lamp) within thirty days after their receipt by the customer.

NOTE—Where the number of lamps used in a year by the customer is comparatively small, so that a number of shipments from the manufacturer would be required in order that two per cent of the entire number should equal twenty lamps, two per cent of each shipment may be sent to the bureau within thirty days after each shipment, and the test not made or ordered by the customer until twenty lamps have been received by the bureau, provided that such test is ordered within one year from the receipt of the samples from the first shipment.

3. Where tests are requested to determine the value of the lamp by burning it at its marked voltage, an initial test will first be made on lamps furnished, which, as above provided, must represent not less than two per cent of the lamps, the value of which is to be determined. One-half of these, which most nearly represent the average result obtained on the initial test, will be burned at their marked voltage until their value is determined, in accordance with the guarantee. Should any lamp be accidentally broken during the test, its place shall be taken by a reserve lamp, which,

on initial test, most nearly represents the broken one. The average result obtained from the test of these samples determines the value of the lamps represented by the samples.

4. The results obtained by tests made by the bureau should, by agreement on the part of lamp manufacturers and of customers who avail themselves of the services of the bureau, be final, claims being settled in accordance with its findings, upon a definite basis agreed upon between manufacturer and customer.

In order that the proposed bureau shall be of value enough to entitle it to the support of lamp companies and their customers, a definite basis of value for a lamp should be determined by agreement between manufacturers and their customers who are to support the bureau. Though lamp companies should be at liberty to guarantee their product at as high a standard of quality as they see fit, the general lines on which such quality is to be determined should be agreed upon by all concerned. The following basis is, herefore, suggested:

1. The effective life of a lamp is to be considered as ending when the lamp reaches some certain percentage of its initial candle-power reading, the value of a lamp being determined by the candle hours given by burning the lamp at its marked voltage and taking readings of candle power at intervals of one hundred hours, until the candle power falls to .... per cent of its initial-rated candle power at the marked voltage; or should the lamp tested burn out before reaching .... per cent of its initial candle power, it is credited with its actual performance.

Initial readings should be the secondary, and of small value compared to the actual performance of the lamp in service, though manufacturers should guar-

antee their lamp for an individual variation in candle power of not to exceed .... per cent, and an average variation of not to exceed .... per cent. Economy or watts should allow for an average variation of not to exceed .... per cent.

2. The guarantee to the customer should provide that, where the customer requests a test made by the bureau, the cost of the test is to be paid, and certain penalties observed, as follows:

If an initial test only is requested, where one or more lamps are found outside the guaranteed initial range as to candle power, the customer is entitled to a .... per-cent reduction in price of lamps represented by the samples furnished the bureau. If average economy is found outside the guaranteed range, the customer is entitled to a .... per-cent reduction. The cost of the above initial test is to be paid by the customer if the lamps are found inside the guarantee, and by the manufacturer if found outside.

Where tests are requested to determine the area, or candle hours, an initial test will first be made on lamps furnished, which, as hereinbefore provided, must represent not less than two per cent of the lamps, the value of which is to be determined. One-half of those that most nearly represent the average result on initial test will be burned at their marked voltage, and the candle hours determined.

The average results obtained from the test of these samples determine the value of the lamps represented by the samples. Should the average candle hours, or area, fall below the guarantee not more than .... per cent, the manufacturer shall only pay the cost of the test. Should the candle hours, or area, fall more than .... per cent and less than .... per cent below the guarantee, the customer is entitled to a .... per-cent

reduction in price of lamps represented by the lamps tested, and the manufacturer to pay the cost of the test. Should the average candle hours or area fall below the guarantee by more than .... per cent, and less than .... per cent, the customer is entitled to a .... per-cent reduction in price of lamps, and the manufacturer to pay the cost of the test.

The above percentage of reduction, or penalty, to be continued in proportion until the customer obtains the lamps (no charge), the manufacturer paying the cost of the test.

Should the average candle hours, or area, be at or above the guarantee, the customer shall pay the cost of the test.

As provided, where tests are requested by the customer, check should be sent to the bureau before the test is made, covering the estimated cost of the test.

Although not an important point, I believe it would greatly stimulate advance in quality of lamps, to the benefit of both consumer and reputable manufacturers, if every six months the average results of all tests made on the product of different manufacturers were published in the electrical journals, such results to separate various economies, and placing in different classes lamps of voltages from forty-five to sixty volts, and lamps from 100 to 125 volts; also separate results on any test which might be made on lamps from 200 to 250 volts.

## PAPERS TO BE READ AT THE CONVENTION

I am happy to submit the following list of papers to be read at the convention, and the names of the authors are a guarantee that the papers to be read

will be of a high order of merit. Some of the manuscript is already in the hands of the secretary, and, depending upon the assurance of the authors that their manuscript will be forwarded at an early date, it is expected that printed copies of each of the papers will be furnished members a reasonable time before the date of the convention.

Bean, W. Worth, St. Joseph and Benton Harbor Railway and Light Company. "Municipal Lighting."

Cahoon, J. B., Elmira Illuminating Company. "Standardizing Prices for Incandescent Light and Power."

Edgar, C. L., Boston Edison Illuminating Company. "Correct Method for Charging for Product."

Jewell, W. S., Toledo Traction Company. "Cost of Delivery of Current from Station to Customer."

Martin, T. C., Editor *Electrical Engineer*. "The Daylight Work of Central Stations."

Stillwell, L. B., Cataract Construction Company. "Electrical Development at Niagara."

Thomson, Prof. Elihu, Lynn, Mass. "Recent Progress in Arc Lighting."

White, J. G., White-Crosby Company. "The Niagara Power Transmission Line."

Chas. A. Carus-Wilson, Professor, Professor of Electrical Engineering at McGill University, Montreal; member Institute Electrical Engineers, New York and London. "The Induction Factor, a New Basis of Dynamo Calculation and Classification."

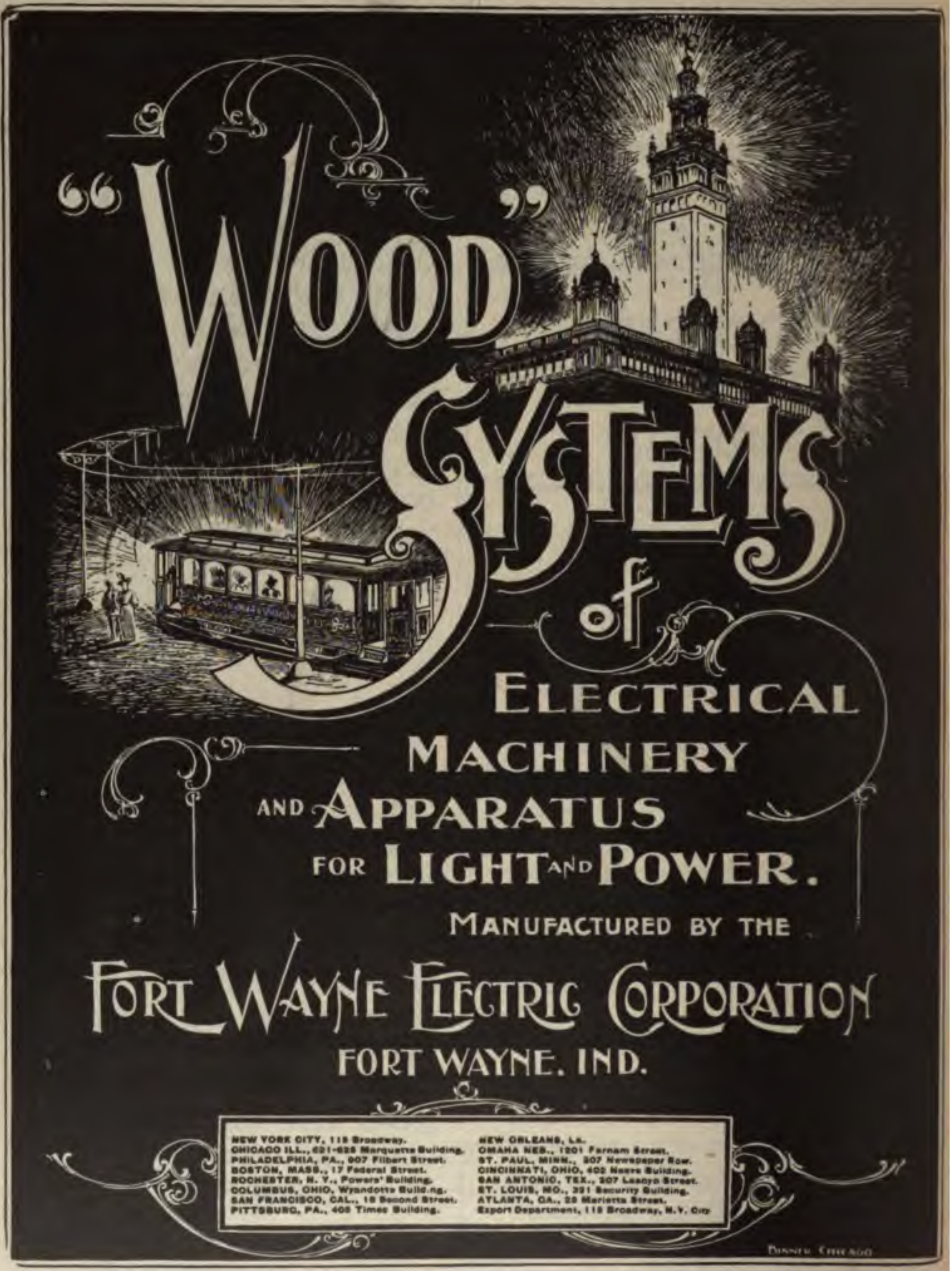
Wright, Arthur, President Municipal Electrical Association, England. "The Profitable Extension of Central Stations."

Yours faithfully,

FREDERIC NICHOLLS,

President.

NEW YORK, March 5th, 1897.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SAN ANTONIO, TEX., 207 Losoya Street.
ST. LOUIS, MO., 321 Security Building.
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